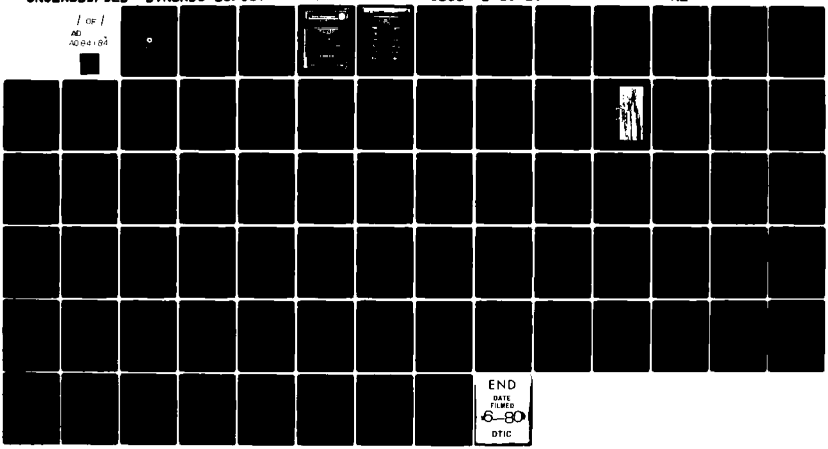
AD-A084 184 DAVID W TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CE--ETC F/G 13/10
COMPARATIVE SHIP PERFORMANCE SEA TRIALS FOR THE U.S. COAST GUAR--ETC(U)
MAR 80 D A WOOLAVER, J B PETERS MIPR-Z-70099-9-914126-A
UNCLASSIFIED DTNSRDC-80/037 USCG -D-10-80 NL



Report No. CG-D-10-80

ADA084184

COMPARATIVE SHIP PERFORMANCE SEA TRIALS FOR THE U.S. COAST GUARD CUTTERS MELLON AND CAPE CORWIN AND THE U.S. NAVY SMALL WATERPLANE AREA TWIN HULL SHIP KAIMALINO

DENNIS A. WOOLAVER
J. BROOKS PETERS

FINAL REPORT

~~FEBRUARY~~ MAR 1980

Document is available to the public through the National Technical Information Service, Springfield, Virginia 22151

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
United States Coast Guard
Office of Research and Development
Washington, D.C. 20590

80 5 5 133

Technical Report Documentation Page

1. Report No.
CG-D-10-80

2. Government Accession No.
AD-A084 184

3. Recipient's Catalog No.
SF43421211, ZF43421001

4. Title and Subtitle
COMPARATIVE SHIP PERFORMANCE SEA TRIALS FOR THE U.S. COAST GUARD CUTTERS MELLON AND CAPE CORWIN AND THE U.S. NAVY SMALL WATERPLANE AREA TWIN HULL SHIP KAIMALINO.

5. Report Date

6. Performing Organization Code

7. Author(s)
Dennis A. Woolaver ~~and~~ J. Brooks Peters

8. Performing Organization Report No.
~~DTNSRDC-79/110~~

9. Performing Organization Name and Address
David W. Taylor Naval Ship Research
and Development Center
Bethesda, Maryland 20084

10. Work Unit No. (TRAIS)

11. Contract or Grant No.
MIPR-Z-70099-9-914126-A

12. Sponsoring Agency Name and Address
United State Coast Guard Headquarters
2100 Second Street, S.W.
Washington, D.C. 20593

13. Type of Report and Period Covered
Final

14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract
~~During April and May 1978, the David W. Taylor Naval Ship Research and Development~~ Center participated in a ~~unique~~ set of comparative ship performance trials conducted jointly by the United States Navy and the United States Coast Guard. These trials consisted of the side-by-side operation of the 378-foot ~~Coast~~ Guard Cutter MELLON, the 95-foot ~~Coast Guard~~ Cutter CAPE CORWIN, and the 89-foot ~~United States Navy~~ (USN) small waterplane area twin hull (SWATH) ship KAIMALINO in seas of opportunity for three 8-hour periods at different relative headings to the sea, with an additional continuous 36-hour trial period involving only the CAPE CORWIN and the KAIMALINO. Within this trial period there were five 8-hour periods wherein six test subjects per vessel were monitored for physiology and affective state while undergoing a series of human factors experiments designed to evaluate the effects of vessel habitability and ship-motion-related degradation on the task performance of experienced sailors. The suitability of the SWATH for typical Coast Guard missions currently performed by conventional surface ships can be addressed through ~~the~~ interpretation of these trial results.

This report documents ~~the~~ trial details and recording procedures; identifies the measurements recorded by DTNSRDC; briefly describes the analysis techniques ~~employed~~; presents ~~the~~ results of those analyses; and comments on these results, drawing conclusions as appropriate. This material ~~is intended~~ to complement additional reports currently under preparation by the U.S. Coast Guard which primarily address the human ~~factors aspects of this trial.~~

17. Key Words
SWATH
Human Factors
Ship Motions
Side-by-Side Trials

18. Distribution Statement
Document is available to the U.S. Public through the National Technical Information Service, Springfield, VA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	73	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER DTNSRDC-80/037	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) COMPARATIVE SHIP PERFORMANCE SEA TRIALS FOR THE U.S. COAST GUARD CUTTERS MELLON AND CAPE CORWIN AND THE U.S. NAVY SMALL WATERPLANE AREA TWIN HULL SHIP KAIMALINO		5. TYPE OF REPORT & PERIOD COVERED Final
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Dennis A. Woolaver and J. Brooks Peters		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS David W. Taylor Naval Ship Research and Development Center Bethesda, Maryland 20084		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS (See reverse side)
11. CONTROLLING OFFICE NAME AND ADDRESS United States Coast Guard Headquarters 2100 Second Street, S.W. Washington, D.C. 20593		12. REPORT DATE March 1980
		13. NUMBER OF PAGES 76
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

USCG Cutter MELLON (WHEC-717)
USCG Cutter CAPE CORWIN
USN KAIMALINO
SWATH
Human Factors
Ship Motions
Side-by-Side Trials

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

During April and May 1978, the David W. Taylor Naval Ship Research and Development Center participated in a unique set of comparative ship performance trials conducted jointly by the United States Navy and the United States Coast Guard. These trials consisted of the side-by-side operation of the 378-foot Coast Guard Cutter MELLON, the 95-foot Coast

(Continued on reverse side)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

(Block 10)

Project Numbers: SF 43-411-211, SF 43-411-291, ZF 43-421-001
Work Units: 1568-029, 1568-030, 1568-031, and 1170-119

(Block 20 continued)

Guard Cutter CAPE CORWIN, and the 89-foot United States Navy (USN) small waterplane area twin hull (SWATH) ship KAIMALINO in seas of opportunity for three 8-hour periods at different relative headings to the sea, with an additional continuous 36-hour trial period involving only the CAPE CORWIN and the KAIMALINO. Within this trial period were five 8-hour periods wherein six test subjects per vessel were monitored for physiology and affective state while undergoing a series of human factors experiments designed to evaluate the effects of vessel habitability and ship-motion-related degradation on the task performance of experienced sailors. The suitability of the SWATH for typical Coast Guard missions currently performed by conventional surface ships can be addressed through the interpretation of these trial results.

This report documents the trial details and recording procedures, identifies the measurements recorded by DTNSRDC, briefly describes the analysis techniques employed, presents the results of those analyses, and comments on these results, drawing conclusions as appropriate. This material is intended to complement additional reports currently under preparation by the U.S. Coast Guard which primarily address the human factors aspects of this trial.

Changes made Per Phone call - Jim Cundiff 5/15/80

A

TABLE OF CONTENTS

	Page
LIST OF FIGURES	iii
LIST OF TABLES	v
ABSTRACT	1
ADMINISTRATIVE INFORMATION	1
INTRODUCTION	2
INSTRUMENTATION AND MEASUREMENTS	4
DATA ANALYSIS, PRESENTATION, AND DISCUSSION	7
CONCLUSIONS	11
ACKNOWLEDGMENTS	11
APPENDIX A - HUMAN FACTORS DATA COLLECTION	39
APPENDIX B - GENERAL DISCUSSION OF DATA COLLECTION	49
APPENDIX C - SHIP MOTIONS, ACCELERATIONS, AND WAVE HEIGHT ANALYSIS FORMAT	57
APPENDIX D - ELECTROCARDIOGRAM ANALYSIS FORMAT	61
APPENDIX E - TONE TEST AND TIME ESTIMATION ANALYSIS FORMAT	63
APPENDIX F - TRIAL ANALYSIS OUTPUT	67

LIST OF FIGURES

1 - KAIMALINO, CAPE CORWIN, and MELLON during Side-by-Side Trials	13
2 - Octagon Geometry and Location	15
3 - Extended Mission Geometry Location	16
4 - Location of Test Area and Recording Area on MELLON	17
5 - Location of Test Area and Recording Area on CAPE CORWIN	18

Page

6 - Location of Test Area and Recording Area on KAIMALINO 19

7 - Instrumentation on MELLON 20

8 - Instrumentation on CAPE CORWIN 21

9 - Instrumentation on KAIMALINO 22

10 - Octagon Circuit with Corresponding Relative Ship Headings 23

11 - Significant Double Amplitude Roll and Pitch Angles versus Heading Experienced by MELLON, CAPE CORWIN, and KAIMALINO during Morning and Afternoon Octagon Transits on 1 through 3 May 1978 24

12 - Significant Double Amplitude Heave and Vertical Acceleration versus Heading Experienced by MELLON, CAPE CORWIN, and KAIMALINO during Morning and Afternoon Octagon Transits on 1 through 3 May 1978 25

13 - Significant Double Amplitude Longitudinal and Lateral Acceleration versus Heading Experienced by MELLON, CAPE CORWIN, and KAIMALINO during Morning and Afternoon Octagon Transits on 1 through 3 May 1978 26

14 - Averaged Significant Double Amplitude Roll, Pitch, Heave, Vertical Acceleration, Lateral Acceleration, and Longitudinal Acceleration versus Heading for 1 through 3 May 1978 for MELLON, CAPE CORWIN, and KAIMALINO 27

15 - Significant Wave Height Measured during Trials of 1 through 3 May 1978 28

16 - Representative Wave Spectra Obtained during Trials of 1 through 3 May 1978 29

A.1 - Button Encoder--Clock Board 44

	Page
A.2 - Button Encoder--Encoder Board	45
A.3 - Button Decoder	46
A.4 - Electrocardiogram Detector	47
B.1 - Sample Wave Form	54
B.2 - Gaussian Distribution	54
B.3 - Rayleigh Distribution	55
E.1 - Sketch of Typical Pulse Sequence	65

LIST OF TABLES

1 - MELLON Ship Motion Recorder	30
2 - MELLON Human Factors Recorder	31
3 - CAPE CORWIN Ship Motion Recorder	32
4 - CAPE CORWIN Human Factors Recorder	33
5 - KAIMALINO Ship Motion Recorder	34
6 - KAIMALINO Human Factors Recorder	35
7 - Transducer Location and Polarities Aboard MELLON	36
8 - Transducer Location and Polarities Aboard CAPE CORWIN	36
9 - Transducer Location and Polarities Aboard KAIMALINO	37
10 - Run Number Coding System	37
F.1 - Microfiche Index	67

ABSTRACT

During April and May 1978, the David W. Taylor Naval Ship Research and Development Center (DTNSRDC) participated in a unique set of comparative ship performance trials conducted jointly by the United States Navy and the United States Coast Guard. These trials consisted of the side-by-side operation of the 378-foot Coast Guard Cutter MELLON, the 95-foot Coast Guard Cutter CAPE CORWIN, and the 89-foot United States Navy (USN) small waterplane area twin hull (SWATH) ship KAIMALINO in seas of opportunity for three 8-hour periods at different relative headings to the sea, with an additional continuous 36-hour trial period involving only the CAPE CORWIN and the KAIMALINO. Within this trial period were five 8-hour periods wherein six test subjects per vessel were monitored for physiology and affective state while undergoing a series of human factors experiments designed to evaluate the effects of vessel habitability and ship-motion-related degradation on the task performance of experienced sailors. The suitability of the SWATH for typical Coast Guard missions currently performed by conventional surface ships can be addressed through the interpretation of these trial results.

This report documents the trial details and recording procedures, identifies the measurements recorded by DTNSRDC, briefly describes the analysis techniques employed, presents the results of those analyses, and comments on these results, drawing conclusions as appropriate. This material is intended to complement additional reports currently under preparation by the U.S. Coast Guard which primarily address the human factors aspects of this trial.

ADMINISTRATIVE INFORMATION

This investigation, conducted under the overall management of the United States Coast Guard (USCG), was funded under MIPR Z7099-9-914126A. Both USCG and U.S. Navy funds contributed to the project. U.S. Navy funding support was provided from four Exploratory Development projects, namely: (1) the SWATH Ship Program (SF 43-411-211), (2) the Ship Feasibility Investigations Program (SF 43-411-291), (3) the Ship Performance and Hydrodynamics Program (ZF 43-421-001), and (4) the Advanced Naval Vehicles Concept Evaluation Program.

At DTNSRDC the investigation is identified under Work Units 1568-029, 1568-030, 1568-031, and 1170-119.

INTRODUCTION

A three ship comparative seakeeping trial was conducted a few miles offshore of Honolulu, Hawaii. The United States Coast Guard fleet assets included two ships, two boats, and a photographic helicopter while the U.S. Navy fleet asset consisted of one ship.

This trial, which had a long planning and development stage, had two distinctly different objectives. The objectives were to:

1. Measure the ship-motion-related degradation in the task performance of experienced sailors, i.e., measure the effect of motion on human performance.

2. Evaluate the suitability of a small waterplane area twin hull (SWATH) ship for typical Coast Guard missions currently performed by conventional cutters such as the 210-foot medium endurance cutters and the 95-foot patrol boats.

The MELLON, a 378-foot, 3000-ton, high-endurance cutter (WHEC) (seen in the background of Figure 1) was the lead ship and largest in the trial. The CAPE CORWIN, a 95-foot, 100-ton patrol boat (WPB) (seen in the foreground of Figure 1) represented the smallest ocean-going conventional vessel employed by the Coast Guard. This vessel, of course, is limited in its capabilities by its seakeeping and arrangement characteristics and thus represents an extreme working environment for its crew when deployed at sea. The Navy's 89-foot 200-ton SWATH ship KAIMALINO (seen as the central vessel in Figure 1) was the vessel to be evaluated by comparison of ship motions and human factors trial results obtained from the side-by-side operation of the three vessels on parallel courses.

The trial procedure for the human factors testing consisted of steaming for eight continuous hours in a standard seakeeping octagon pattern. This trial consisted of three days at sea with three ships and three separate groups of human factors test subjects. Each group of subjects consisted of six experienced sailors selected from the officers and crew of MELLON.

Dockside human factor studies were conducted on 29 and 30 April 1978, and again on 4 May 1978 following the at-sea octagon trial period. This dockside testing was used to establish baseline data for the human factors experiments.

On all test days, human factors experiments were planned to begin at 0800 hours and cease at 1600 hours. It was agreed that each distinct human factors test period would occupy 20 minutes of testing, followed by a 10-minute nontesting but monitored period, followed by a 20-minute test period and another 10-minute nontest, but monitored period. This sequence was repeated eight times each day. During at-sea trial days the parallel steaming of each octagon leg was planned to occur during the 20-minute human factors test period, while the consecutive 45-degree course changes to starboard and realignment for continued side-by-side steaming would occur during the 10-minute nontest period. This procedure allowed steady state ship motion values to be directly related to the human factors test data.

Provided in Figure 2 is a sketch of the octagon circuit and its relative location with respect to the island of Oahu, Hawaii. Two complete clockwise transits, beginning with Leg 1 of this pattern, were made on 2 May 1978 and again on 3 May 1978. However, on 1 May 1978, a late start delayed transit of the first leg by 1.5 hours. Since human factors testing had begun at 0800 hours, the octagon pattern could not be completed twice by 1600 hours and was modified on the second circuit as shown in Legs A, B, and C. Human factors testing ceased at 1600 hours which corresponded with the completion of Leg B.

Although it was planned that vessel speeds would be maintained at 10 knots while transiting the octagon legs, mechanical failures first to MELLON and then KAIMALINO caused transit speeds to be reduced to between 7 and 7.5 knots on several occasions. These speed changes, as obtained from USCG logs, are given in the enclosed data.

A second trial phase consisted of the side-by-side operation of the CAPE CORWIN and the KAIMALINO for additional periods of human factors testing on 7 and 8 May 1978 with the vessels remaining at-sea overnight.

These test periods were identical to the previous periods with the exception that instead of transiting the octagon, they steamed within the area shown in Figure 3. The general track of the vessels is shown; however, significant perturbations which occurred in the actual transits are not indicated.

Two vessels, MELLON and KAIMALINO, were equipped with motion stabilizers. The rudder roll stabilization system aboard MELLON was not activated during these trials, since it is a prototype system not found aboard the entire class. However, the automatic control system aboard KAIMALINO, consisting of canards and flaps, was activated and functional during all trial periods except from 0800 to 1223 hours on 7 May 1978.

Ship motion measurements aboard each vessel were recorded continuously while underway and also during the dockside human factors test periods. Details regarding these measurements are contained in the following section.

INSTRUMENTATION AND MEASUREMENTS

MELLON, CAPE CORWIN, and KAIMALINO were instrumented to record roll, pitch, heave acceleration, and the three ship system coordinate axis accelerations (i.e., lateral, longitudinal and vertical). The three coordinate axis accelerations measured in the human factors room of each ship were referenced to the ship axis system, that is, parallel to the deck in a longitudinal direction and perpendicular to the deck in a vertical direction. Additionally, equipment to measure and record the electrocardiograms (EKG) of the six test subjects per vessel, with one event box per subject, was also installed. An event box consisted of a small box with three different colored, normally closed, push activated switches. These boxes were used to record electronically the responses of the test subjects during the tone test and the time estimation test--human factors tests given once each hour during the test periods. Details pertaining to the design of these boxes, as well as operational characteristics, are given in Appendix A. Preconditioning and recording equipment was located near, but not within, the confines designated as the "test area" by the human factors experimenter, as shown in Figures 4, 5, and 6. A DTNSRDC technician monitored this equipment on each vessel during all test periods as well as during transit periods. An eight-channel strip chart recorder which monitored each test subject's EKG trace, the master event box (power on and off condition only) and a human factors analog tape recorder on and off indicator was placed within the test area for the use of the experimenter.

Figures 7, 8, and 9 present schematics of the instrumentation as installed prior to the trial. Tables 1 through 6 provide channel designations for the six tape recorders as well as transducers and conditioning electronics by manufacturer, model, and type. Modifications necessitated by scheduling changes, additional trials, and/or equipment failures are also indicated in these tables. Transducer locations and tape recorder voltage polarities for all vessel motions are provided in Tables 7, 8, and 9.

Wave height data transmitted by the wave buoy were monitored on the MELLON and on the KAIMALINO continuously during the 8-hour octagon transits of 1, 2, and 3 May 1978. Waveheight was not monitored during the 7-8 May trials.

Human factors measurements recorded by DTNSRDC were monitored by the individual experimenters with the strip chart recorder provided them, as mentioned earlier. The application of the three EKG electrodes per subject, the administration of all human factors tests, and all communications with DTNSRDC representatives during the human factors test periods were performed by the experimenter or his aide. Indications as to faulty or weak signals from a test subject's EKG electrodes, button box values, etc., were made known to the experimenter or his aide during the 10-minute intervals between test periods and then only in as unobtrusive a manner as possible.

Data were recorded on the analog tape recorders within a nominal ± 1.4 volts range. To maintain a recording voltage level that was within this range, yet not so low as to impair resolution, the preconditioning electronics, as listed in Tables 1 through 6, were adjusted as necessary to provide the proper gain or attenuation required. These changes were made during the 10-minute periods between human factors test periods. Removal and replacement of recording tape was also accomplished during these periods.

These adjustment values were recorded by the recording technician in his log book. The combination of these gain and attenuation values and the transducer calibrations (when applicable) enable the analysis procedure to apply physical units to the various parameters.

The recording technique used for the EKG channels varied somewhat from that used for the ship motion channels, since the EKG analysis routine was primarily frequency oriented rather than amplitude oriented, i.e., beats per minute. The recording technicians aboard MELLON and CAPE CORWIN selected an amplifier gain which would yield a maximum excursion of approximately 0.5 volts at the analog tape recorder inputs. The dynamic range of this incoming EKG signal was then reference (using the zero adjust on the preconditioning amplifier) to approximately 0.0 volts placing it near the center of the recording range capability. This technique permitted a relatively large signal to be recorded and still allowed for sizable voltage fluctuations both within the trace itself and also the direct current level upon which it was superimposed. Amplification factors (gains) of 200 to 1 were predominately used for the EKG traces upon these two vessels.

Aboard KAIMALINO, the preconditioning amplifiers associated with the EKG channels did not have a referencing (zeroing) capability and, therefore, could not be adjusted to the center of the recording range. To assure that the EKG signal remained within recording range, a smaller amplification factor (gain) was chosen, typically, a value of 100 to 1 was used. This variation resulted in EKG recording levels aboard KAIMALINO to be approximately one-half those aboard the other two vessels.

All data recorded upon the tape recorders are unfiltered as may be seen in Figures 7, 8, and 9. Recorded data are time referenced by the parallel recording of a time code signal which was set to correspond to local time and was synchronized ($\pm$ approximately 2 seconds) between the three vessels. The majority of the collected data was analyzed using this time code reference. An additional reference channel designated "mode" consisted of the presence of a one-half volt signal, indicating a human factors test is being conducted; absence of the signal indicates a period during which course changes were made and no human factors tests were conducted. This auxiliary reference channel was used when the time code signal was disabled or unrecoverable.

Wave height transmissions from the wave rider buoy were monitored continuously while the buoy was deployed. While it was originally intended to deploy the buoy in the center of the octagon, scheduling changes necessitated that it be deployed at the beginning of the first leg as indicated in Figure 2. While the center location would have been preferable, the trial location was chosen to minimize wave height variations which could occur within the limits of the octagon transit. To this end, no significant visual changes could be discerned from leg to leg during the transits and the wave heights recorded are considered to be representative for the octagon transit.

Information received from the event boxes was encoded, recorded, and decoded as described in Appendix A.

DATA ANALYSIS, PRESENTATION, AND DISCUSSION

All data collected by DTNSRDC were recorded on 14 channel FM analog tape recorders as discussed previously. Ship motions and accelerations were analyzed in one of two basic stages, as directed by the Coast Guard. The first stage produces average and standard deviation values for the parameters analyzed as derived from the data point samples. The second stage provides several additional statistical measures, information on the maxima and minima of the time history, tabular and graphic representations of the spectral content, and amplitude distributions of the data. Existing DTNSRDC analysis programs employing accepted statistical procedures were modified to provide the information requested by the Coast Guard trial coordinator.

Appendix A provides a description and discussion of the human factors data collection and analysis with schematics of instrumentation designed specifically for this trial by DTNSRDC. Appendix B gives a brief discussion on data collection and analysis in general and addresses the meaning of several statistical measures. Appendixes C through E detail the data format for the results of the ship motion analysis and human factors analysis which DTNSRDC was tasked to provide. The analysis results are provided on microfiche accompanying this report as detailed in Appendix F. The remainder of this section discusses selected results taken from the dockside and octagon trial periods.

To facilitate data analysis and formatting, a run number coding system, as shown in Table 10, was implemented. Note that the ship type, calendar date, and local clock time are easily derived from the run numbers and that even numbered runs coincide with human factors test periods. The odd numbered runs coincide with transits to and from the test area and with the times allotted to change headings.

Presented in Figure 10 are the relative ship headings associated with each octagon leg. It must be emphasized that no permanent relationship exists between run numbers and ship headings.

Ship motion data recorded during the dockside periods were analyzed for root mean square (RMS) and mean values for the three ship referenced accelerations for CAPE CORWIN only. This technique allowed the human factors experimenters to assess the magnitude of these accelerations for the vessel most likely to yield the highest values. If it appeared that these results warranted additional analysis of dockside motion data, that analysis could then be performed. It was determined that CAPE CORWIN acceleration magnitudes did not indicate that the additional analysis for the other vessels would be required.

Vessel motions for the octagon transits of 1 through 3 May are presented in Figures 11 through 14. Figure 11 presents significant double amplitude roll and pitch angles versus ship relative heading for all three vessels during the morning and afternoon octagon transits. A heading of 180 degrees indicates head seas. Several points are to be noted: first, it is obvious that CAPE CORWIN experiences significantly more rolling and pitching motion than the other vessels; second, the motions experienced during the morning (solid line) transits are generally larger than those of the afternoon; and third, while the pitching motions of MELLON and KAIMALINO are comparable, MELLON (like CAPE CORWIN) tends to experience greater roll angles--especially in following seas.

Heave accelerations and vertical accelerations are presented in Figure 12 in a format identical to that of the last figure. Once again we find that CAPE CORWIN experiences larger motions than do MELLON or KAIMALINO which are comparable. No heave data are shown for MELLON on 3 May and no vertical acceleration is shown for KAIMALINO on the same day. Due to the relative proximity of the heave and vertical accelerometers on these vessels, and since roll and pitch angles are relatively small, substitution of heave acceleration for vertical acceleration, or vice versa, may be made to approximate these results.

Presented in Figure 13 are longitudinal and lateral accelerations in a similar format. Note that the ordinate used is identical to that of Figure 12 allowing one to perceive the relative magnitudes of these translational motions with those in the vertical direction. It is seen that longitudinal accelerations are comparable for all vessels and remain near or below 0.08 g. Values of lateral acceleration show that CAPE CORWIN experiences the highest values, KAIMALINO the lowest, and MELLON is in between. Note that MELLON experiences lateral acceleration values which exceed her vertical acceleration values--especially in following seas.

The average of the values shown in Figures 11 through 13 are presented in Figure 14. These average values represent the average value for each parameter for a given relative ship heading for 1, 2, and 3 May 1978. While one must remember that sea conditions changed over the course of the trial and that ship speeds varied from 7 to 10 knots, Figure 14, nevertheless, presents data which show relative trends between the classes. This is one of the primary reasons that comparative seakeeping data should be obtained by conducting side-by-side trials. We see that for all motions except longitudinal acceleration, CAPE CORWIN clearly experiences the greatest motions. KAIMALINO appears to experience generally less motion than MELLON.

Seaway data collected during the octagon transits are presented in Figure 15 as significant wave height. The significant value is the average of the one-third highest double amplitudes within the sample studied and corresponds closely to the value a trained observer would ascribe to the wave height within a seaway. While wave heights remained relatively constant, with values ranging from 1.2 to 1.6 meters, the nature of the seaway changed markedly over the three days as shown by the spectra in Figure 16.

During the morning of 1 May, the seaway consisted of a primary swell system approximately 1.0 to 1.5 meters in height from 090 degrees with a secondary swell from 135 degrees approximately 0.50 meters in height. The ship course for the first octagon leg was always chosen to be into the primary waves. As may be seen in the spectra for 1030 and 1300 hours on 1 May, the seaway also contained a small amount of wind waves as evidenced by the relatively broad spectral shape. The morning of 2 May was similar to that of 1 May, the wave height being slightly higher as shown by the larger area under the spectral shape, and containing more wind waves. However, the afternoon spectra (1300 hours) indicates that the sea consisted of two swell systems of almost the same frequency and little or no significant wind waves. By the morning of 3 May, these two swell systems have separated in frequency somewhat, as shown by the two distinct peaks in the 1030 hour spectra. The lower frequency peak represents a longer swell of approximately 500 meters wavelength and about 0.5 meter in height. The remaining seaway consists of a shorter swell (100 meters wavelength) and wind waves bringing the total significant height up to 1.5 meters.

All of the spectra shown in Figure 16 are representative of a State 3 sea. While relatively good diversity is indicated within and among the various days, one must not arbitrarily extend the limited results of these trials to other seaways.

CONCLUSIONS

The following conclusions may be extracted from the trials:

1. The wave height encountered during the trials is representative of low to average conditions throughout the world's oceans at any given time.

2. The narrow range of sea conditions encountered precludes any conclusions relating to overall seaworthiness characteristic comparisons between the three craft. It may, however, be stated that up until the inception of cross structure slamming of KAIMALINO, the KAIMALINO should provide a much more stable platform than CAPE CORWIN.

3. None of the vessels were seaway limited in their ability to maintain course and speed; however, the main deck of CAPE CORWIN did occasionally experience wetness due to spray while KAIMALINO and MELLON remained dry throughout the trials.

4. Motion comparisons across trial days indicate that KAIMALINO was least affected by seaway changes while CAPE CORWIN was most affected.

5. KAIMALINO was the most stable of the three vessels, being superior to MELLON in roll and lateral acceleration, and superior to CAPE CORWIN in roll, pitch, heave, vertical acceleration, and lateral acceleration.

6. It is feasible to conduct multiship side-by-side trials of a complicated nature.

ACKNOWLEDGMENTS

The multiship side-by-side trials discussed in this report received the active support of many individuals. Primary among those in the Coast Guard were Messrs. Thomas Milton and David Walden, Project Coordinators; Captain Jack Cadigan, Captain of MELLON, and On Scene Commander; LT Michael Dobrovic, Commanding Officer of CAPE CORWIN; and LT Steven Wiker, Human Factors Test Coordinator and Experimenter on CAPE CORWIN. Mr. Michael McCauley and Dr. Ross Pepper, Human Factors Test Experiments on MELLON and KAIMALINO, respectively, were responsible for the efficient smooth collection of human factors data on those vessels. Commanders Kenneth Williams and Dennis Freezer, USCG 5th District, and Commander

Pete Dickerson, USCG 14th District were responsible for the scheduling of the myriad parts, pieces, people, and vessels required throughout the trials.

The author also wishes to thank the following Center personnel: Mr. Seth Hawkins and Dr. Dave Moran who coordinated the Trial Analysis and funding, along with the actual trial effort with the Coast Guard; Mr. Wah Lee, responsible for the data analysis; Mr. Steven McGuigan, responsible for the human factors data collection hardware and analysis; and Mr. Ary Baitis, Mr. Edward Foley, Mr. Gordon Minard, Mr. William Dixon, and Mr. Robert Stanko, responsible for the installation, documentation, and collection of the trial data. Also, Mr. Geoffrey Cox and Mr. Harry Jones whose aid and guidance in the preparation of the final manuscript is most appreciated.

The enthusiasm, professional guidance, and experience which these individuals, along with the officers and crews of MELLON, KAIMALINO, and CAPE CORWIN, gave to the trial effort are responsible for its successful completion.

Figure 1 - KAIMALINO, CAPE CORWIN, and MELLON during Side-by-Side Trials

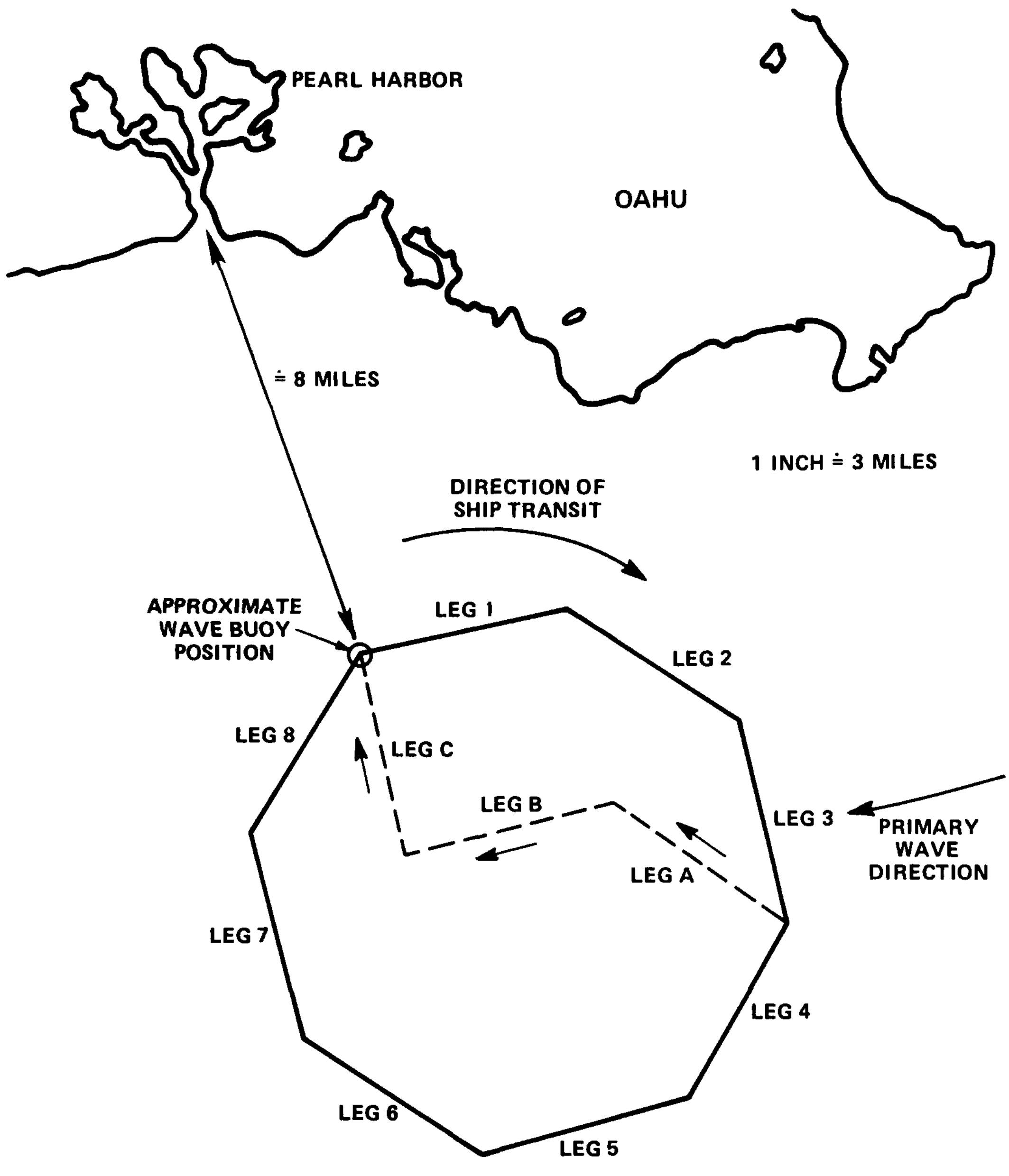


Figure 2 - Octagon Geometry and Location

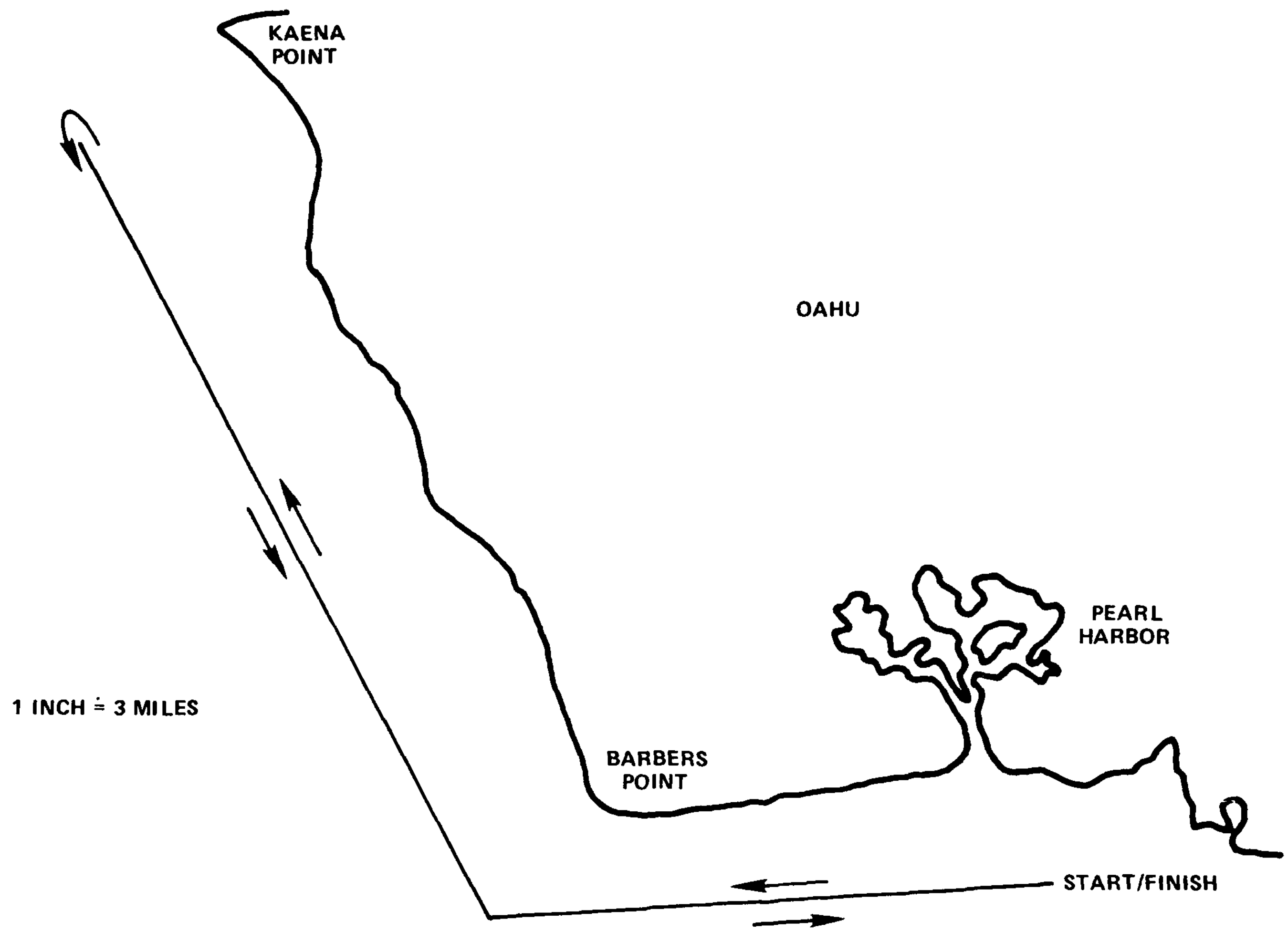


Figure 3 - Extended Mission Geometry Location

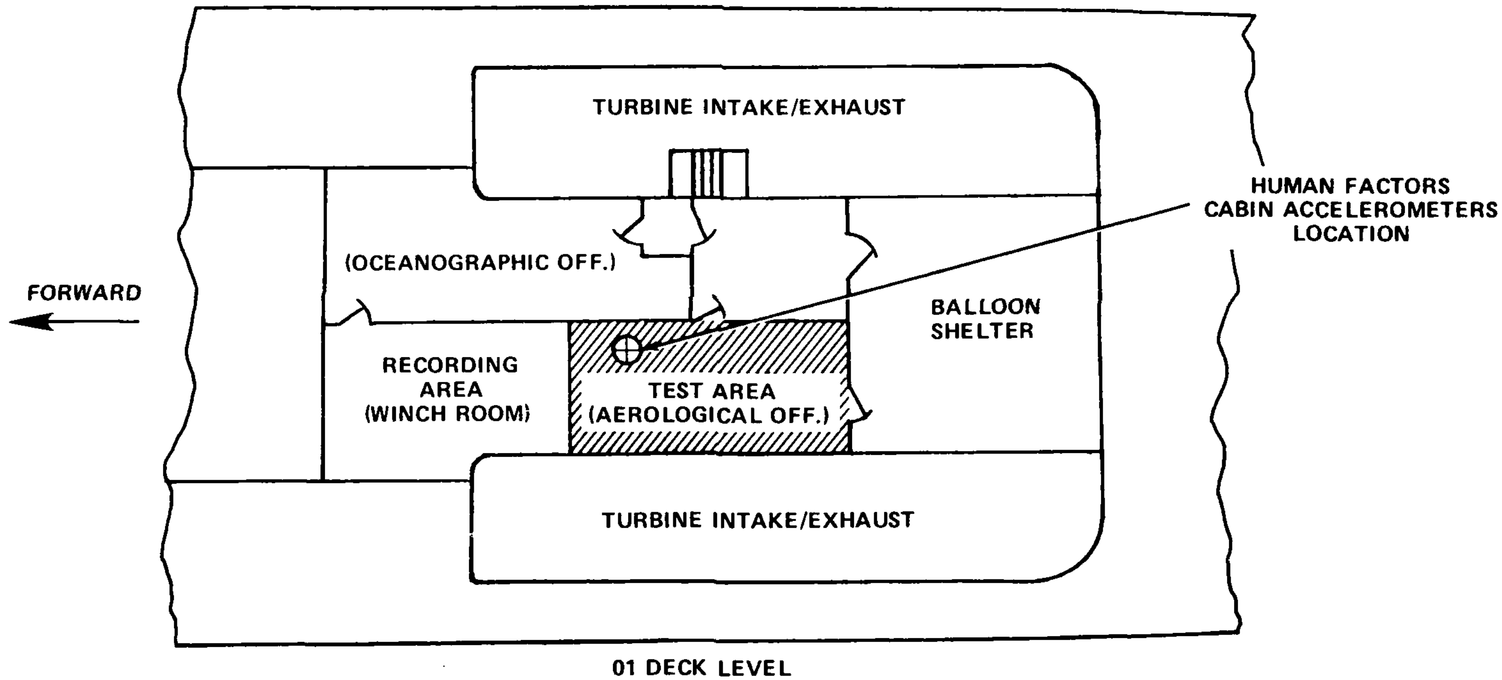


Figure 4 - Location of Test Area and Recording Area on MELLON

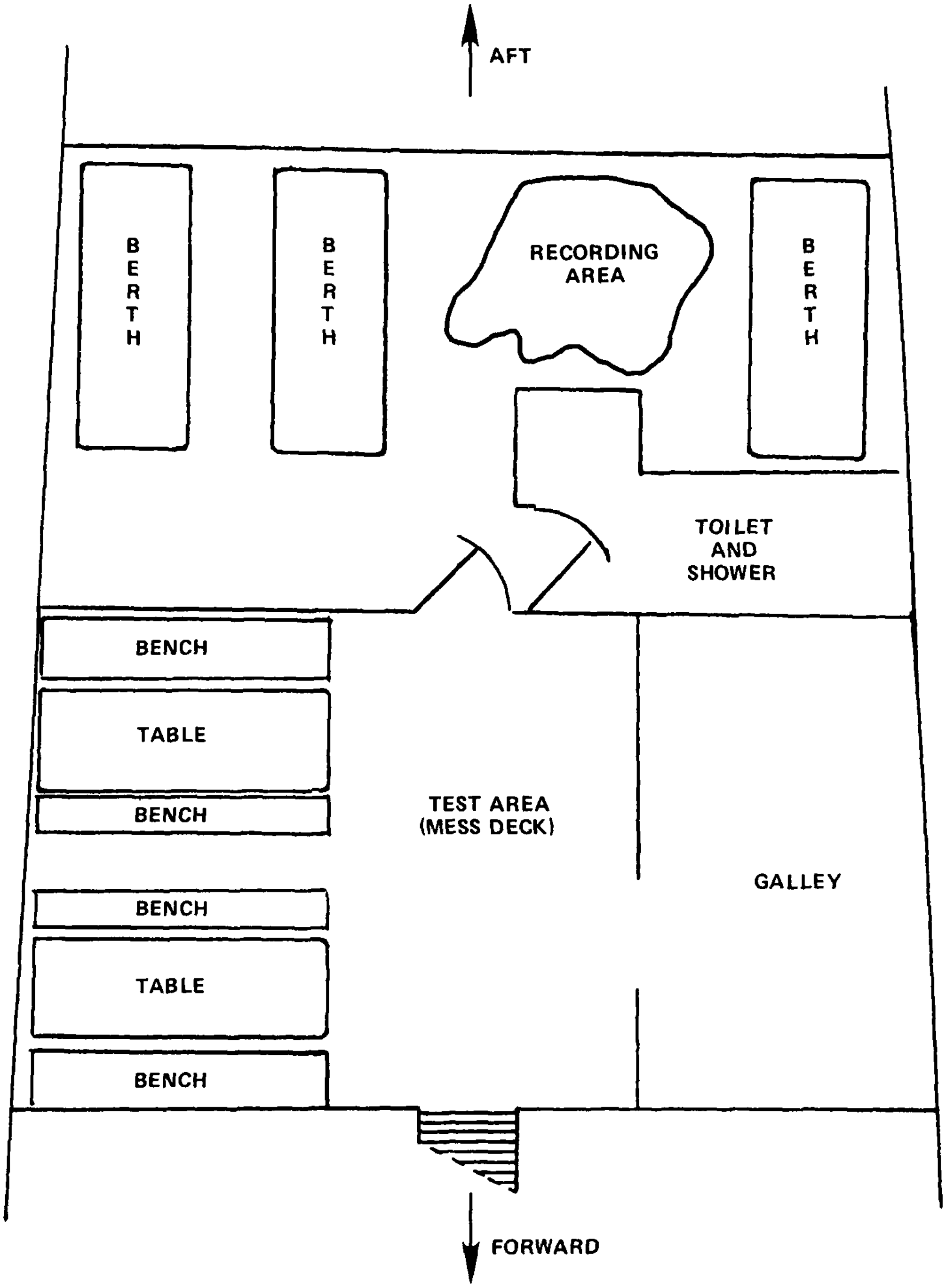
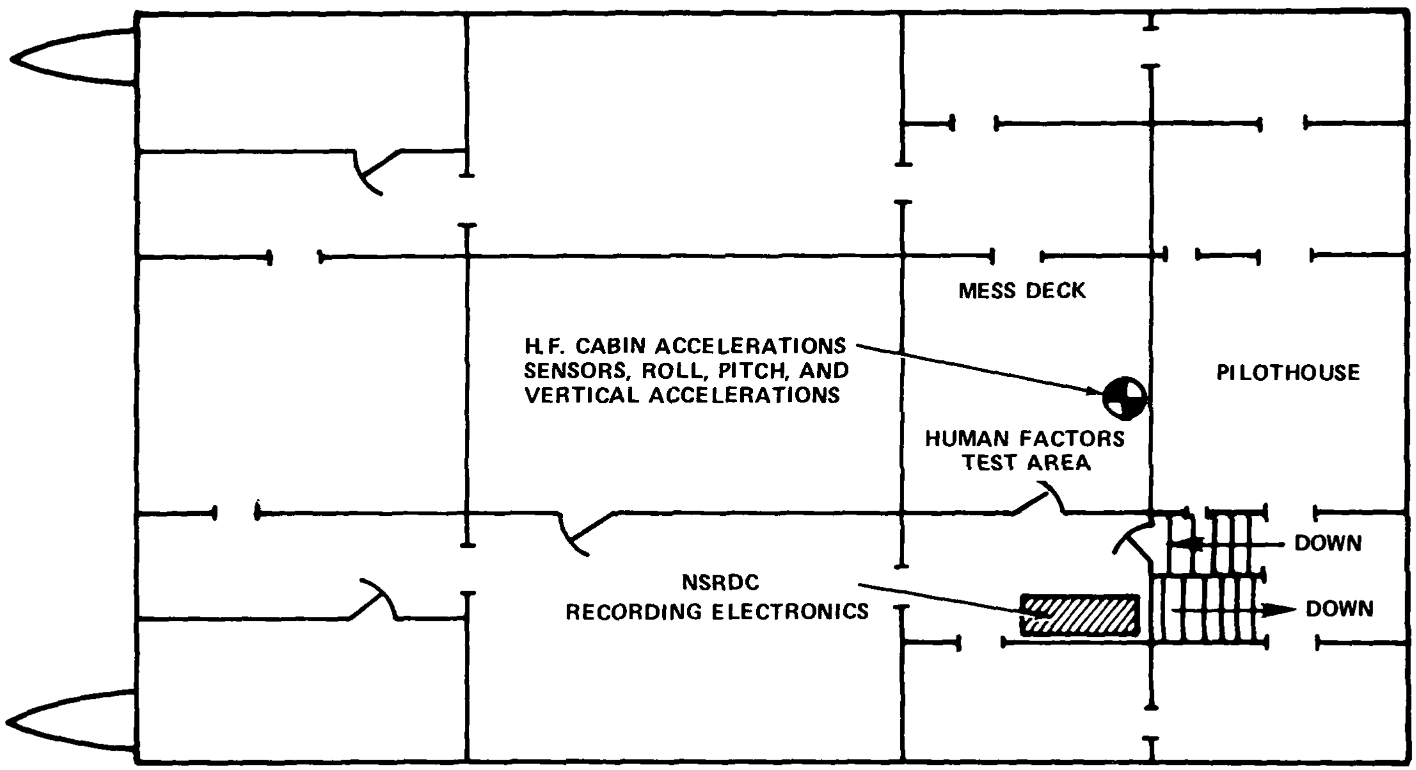


Figure 5 - Location of Test Area and Recording Area on CAPE CORWIN



PLAN VIEW OF SECOND DECK
AND PILOTHOUSE DECK
(1 1/2 LEVEL)

Figure 6 - Location of Test Area and Recording Area on KAIMALINO

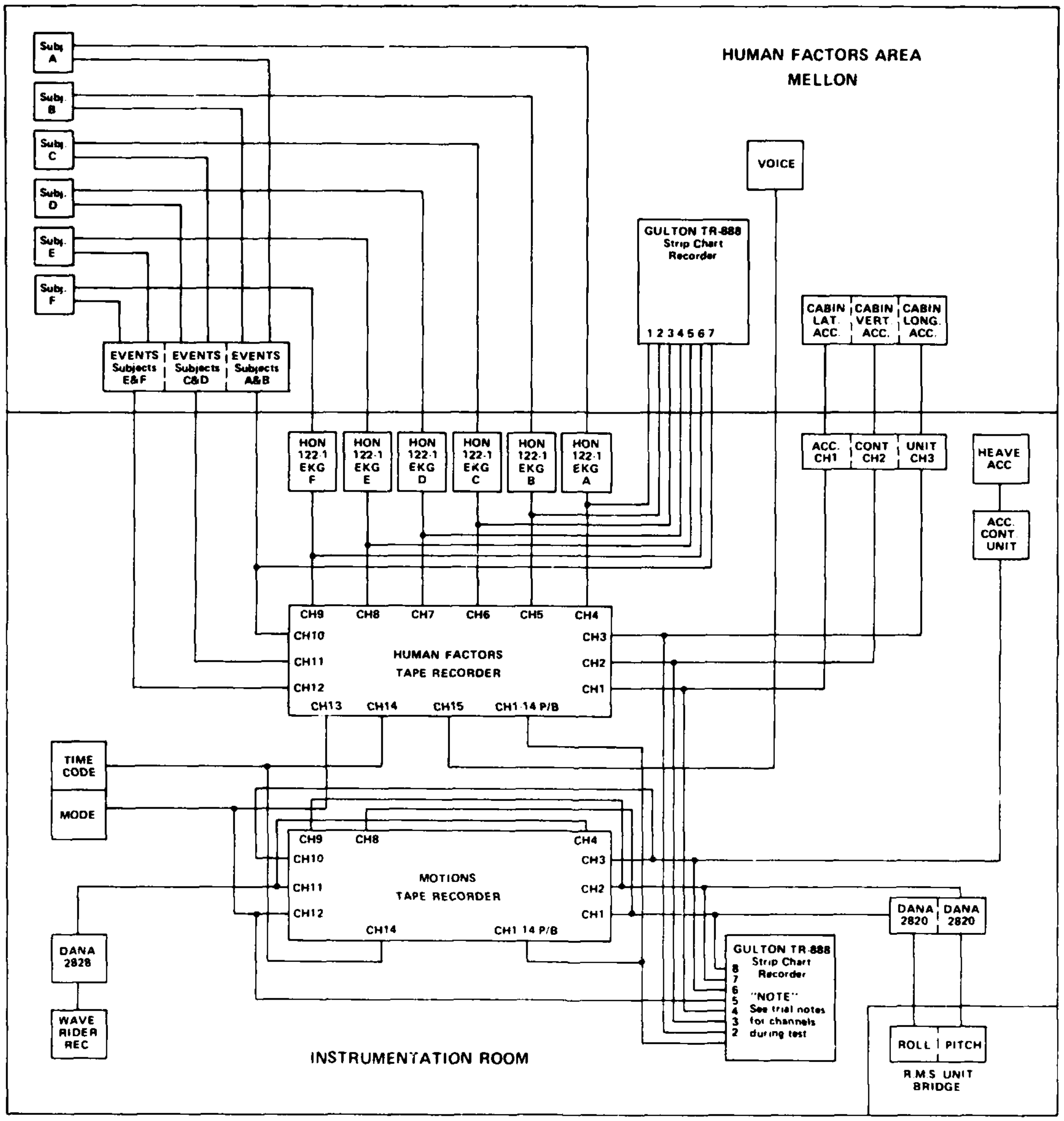


Figure 7 - Instrumentation on MELLON

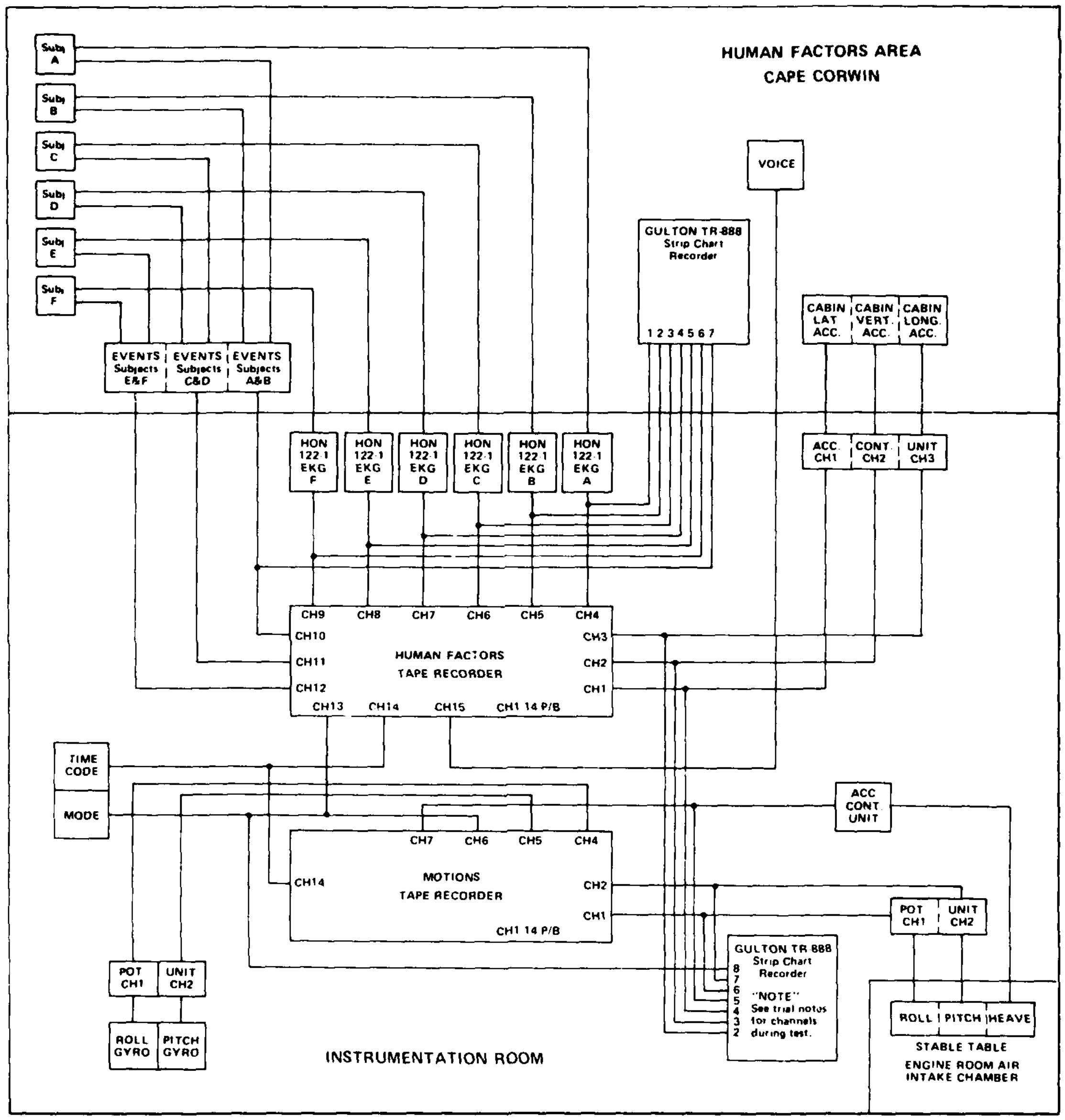


Figure 8 - Instrumentation on CAPE CORWIN

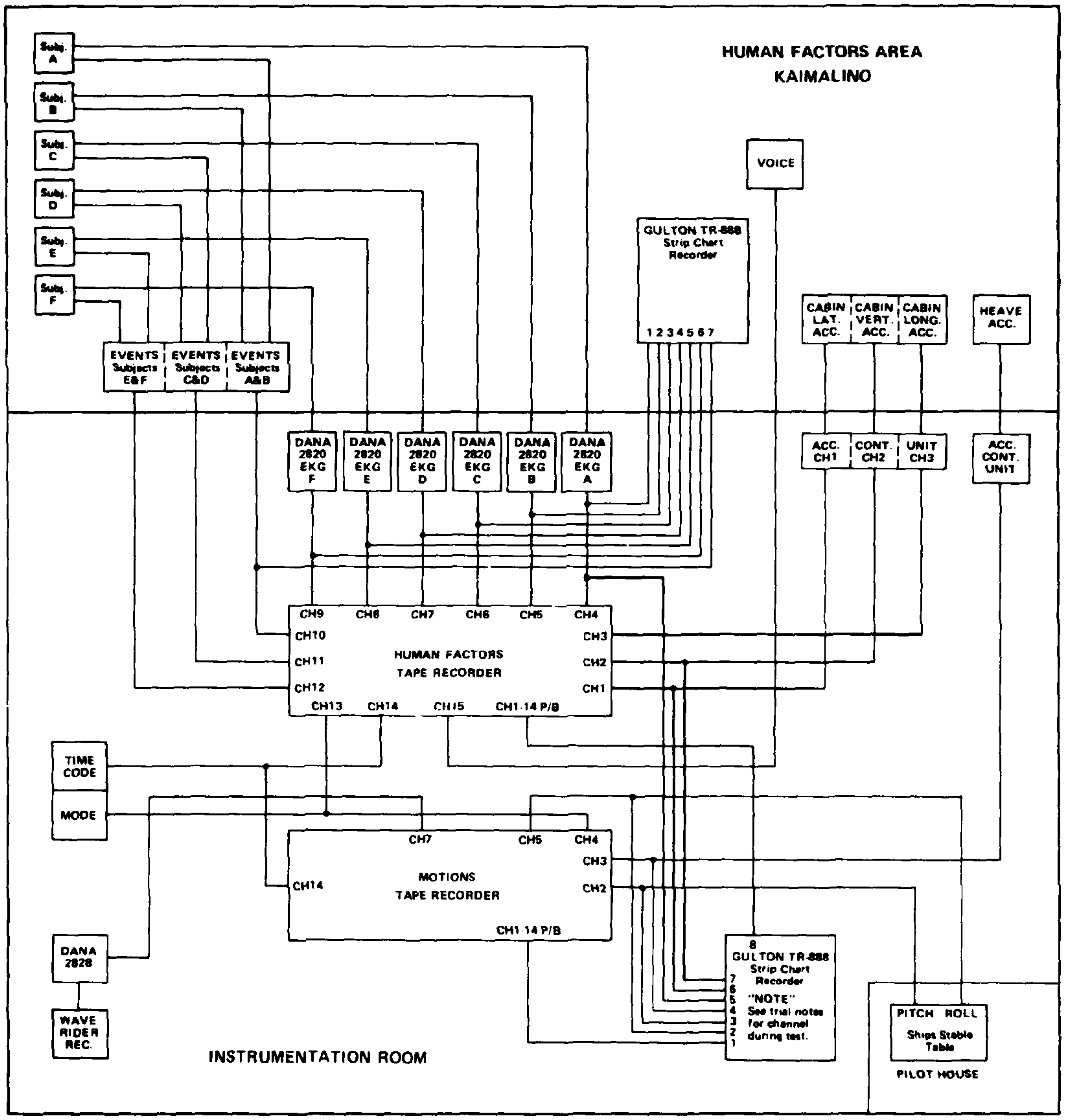


Figure 9 - Instrumentation on KAIMALINO

LEG NUMBER	RELATIVE SHIP HEADING
1	180 Degrees (HEAD SEAS)
2	225 Degrees
3	270 Degrees (PORT BEAM)
4	315 Degrees
5	360/000 Degrees (FOLLOWING)
6	45 Degrees
7	90 Degrees (STBD BEAM)
8	135 Degrees

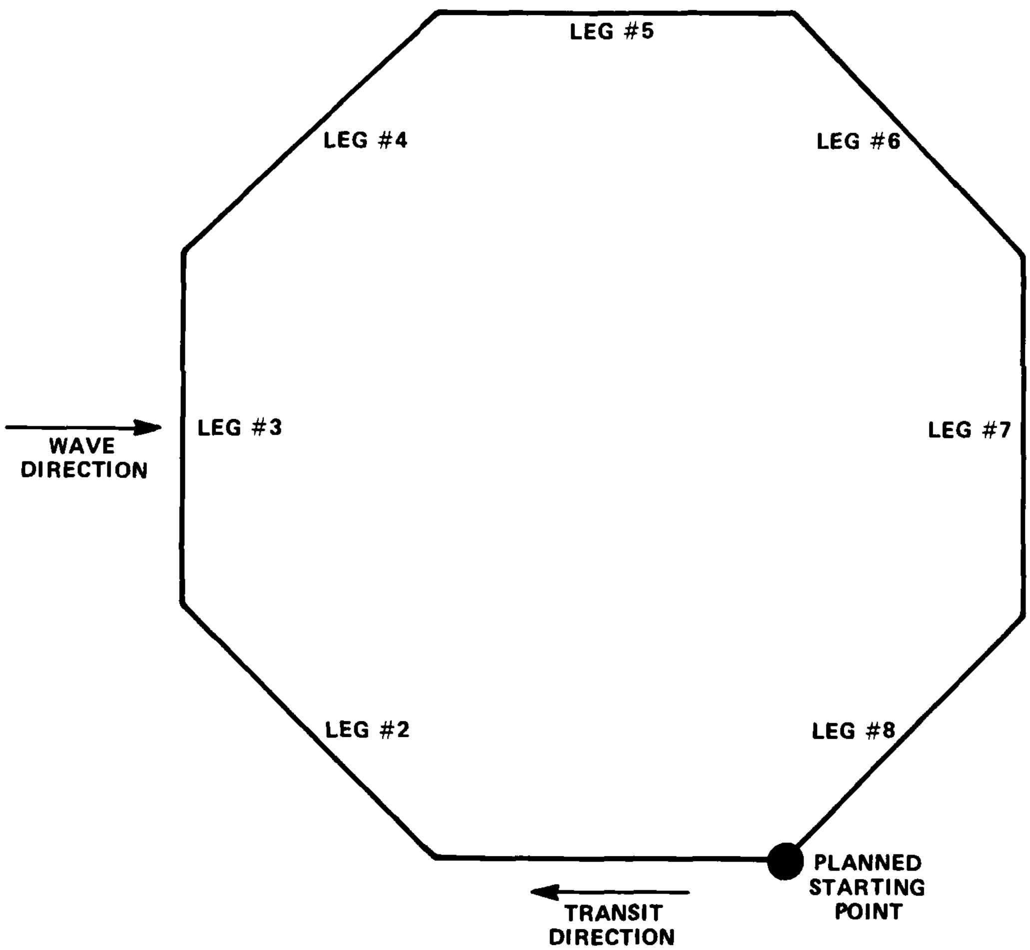


Figure 10 - Octagon Circuit with Corresponding Relative Ship Headings

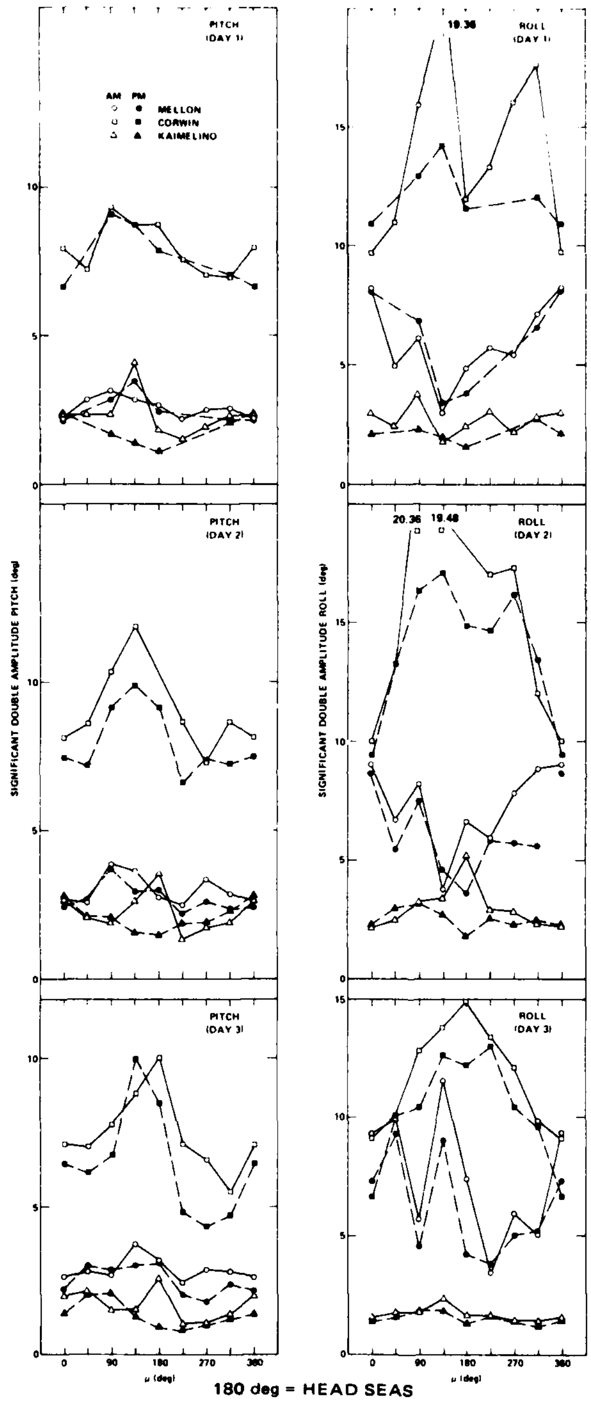


Figure 11 - Significant Double Amplitude Roll and Pitch Ang versus Heading Experienced by MELLON, CAPE CORWIN, and KAIMALINO during Morning and Afternoon Octagon Transits on 1 through 3 May 1978

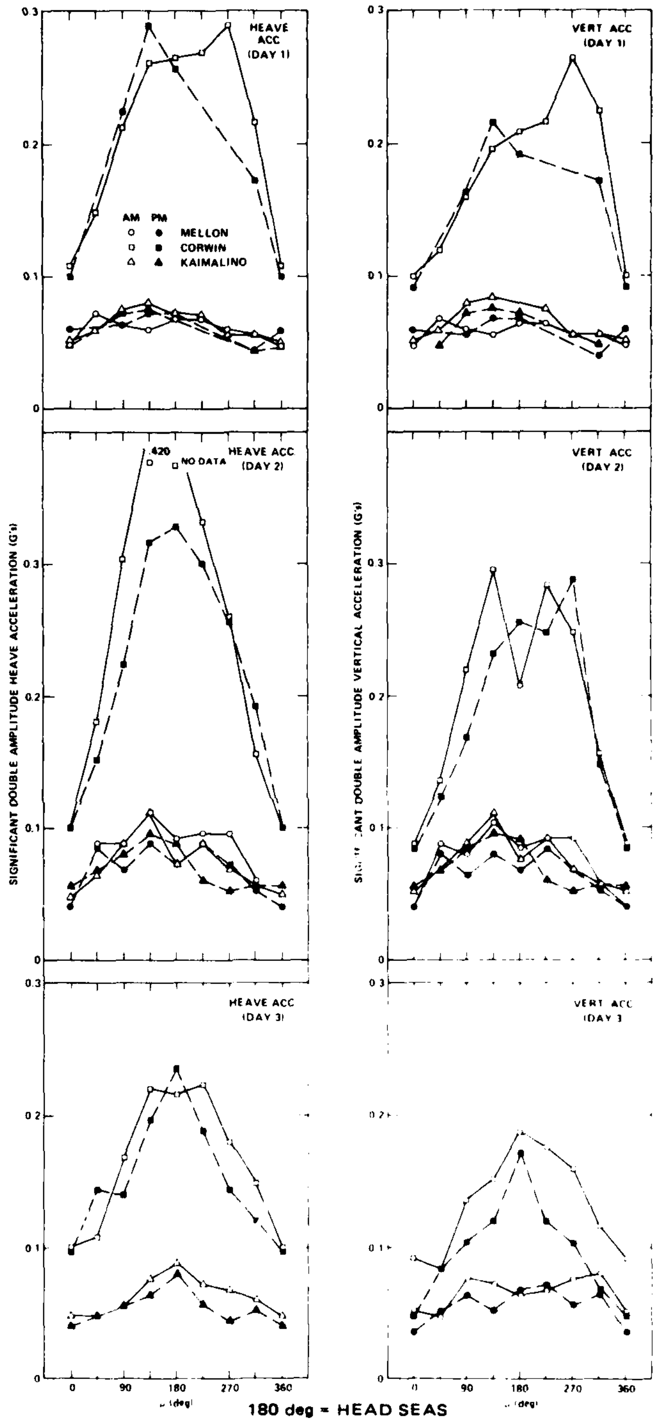


Figure 12 - Significant Double Amplitude Heave and Vertical Acceleration versus Heading Experienced by MELLON, CAPE CORWIN, and KAIMALINO during Morning and Afternoon Octagon Transits on 1 through 3 May 1978

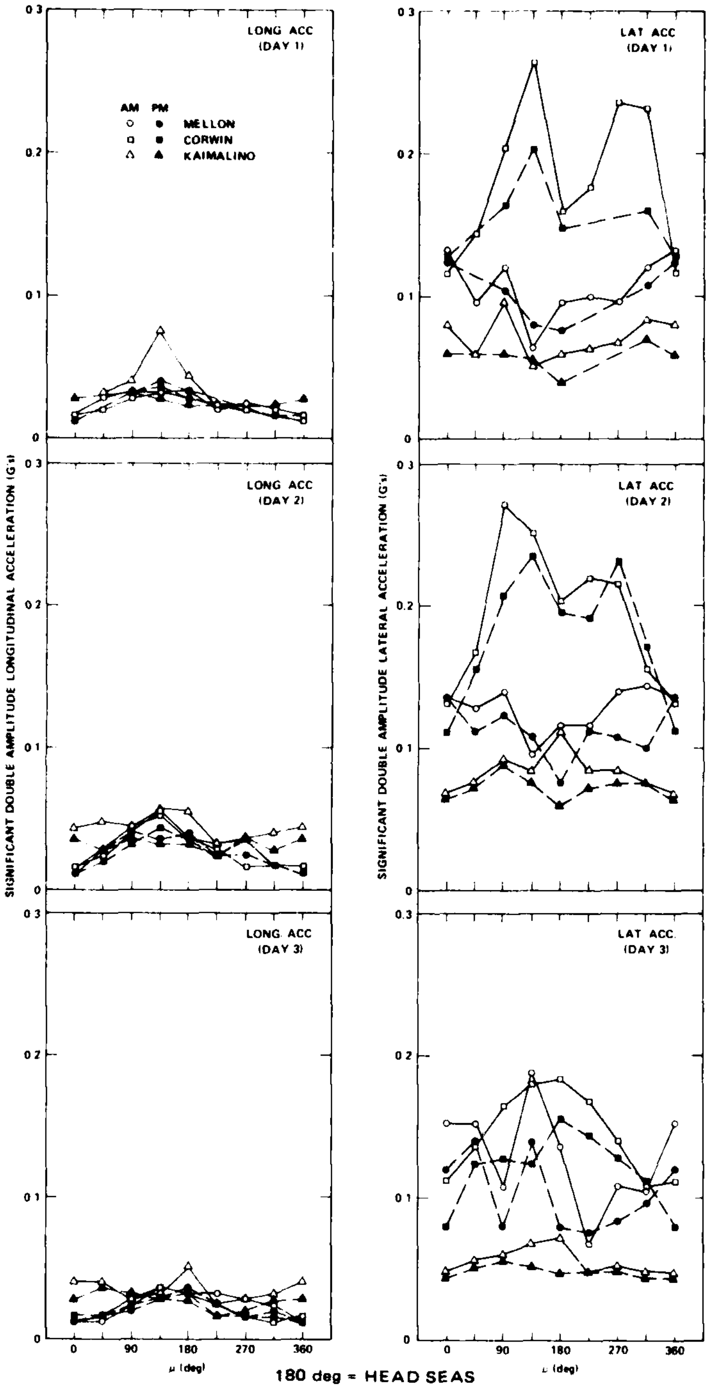


Figure 13 - Significant Double Amplitude Longitudinal and Lateral Acceleration versus Heading Experienced by MELLON, CAPE CORWIN, and KAIMALINO during Morning and Afternoon Octagon Transits on 1 through 3 May 1978

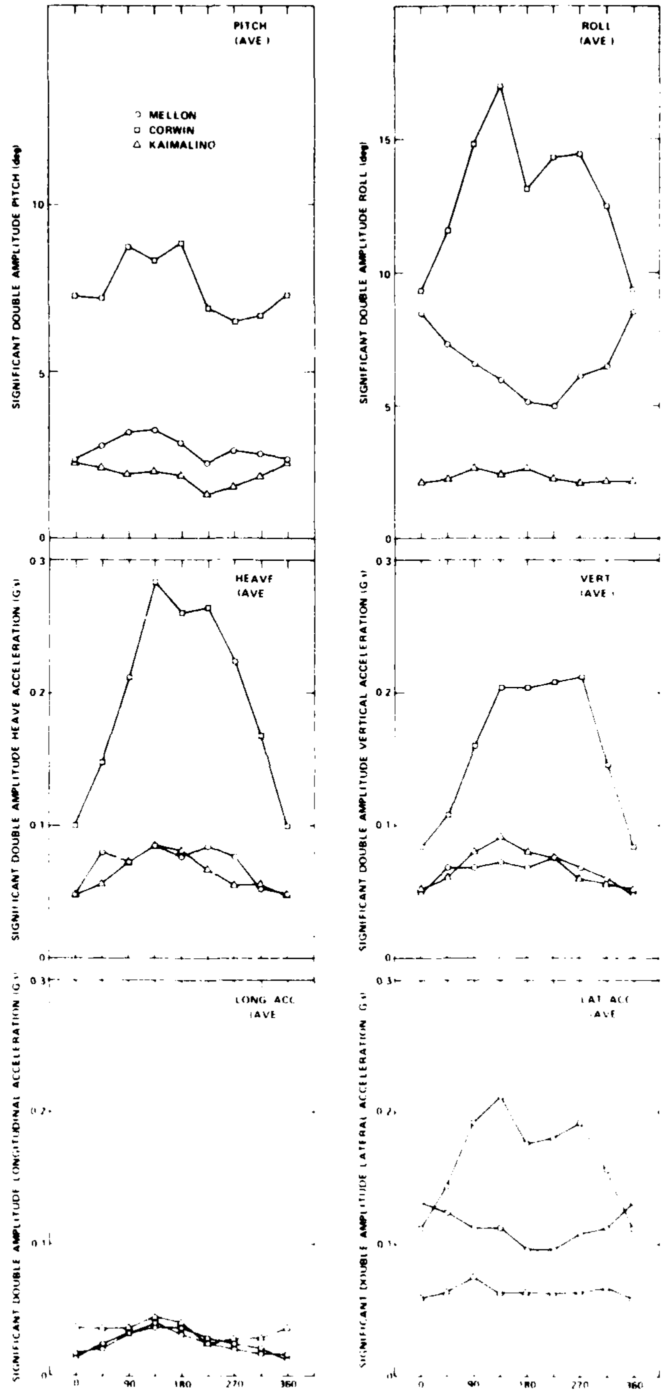


Figure 14 - Averaged Significant Double Amplitude Roll, Pitch, Heave, Vertical Acceleration, Lateral Acceleration, and Longitudinal Acceleration versus Heading for 1 through 3 May 1978 for MELLON, CAPE CORWIN, and KAIMALINO

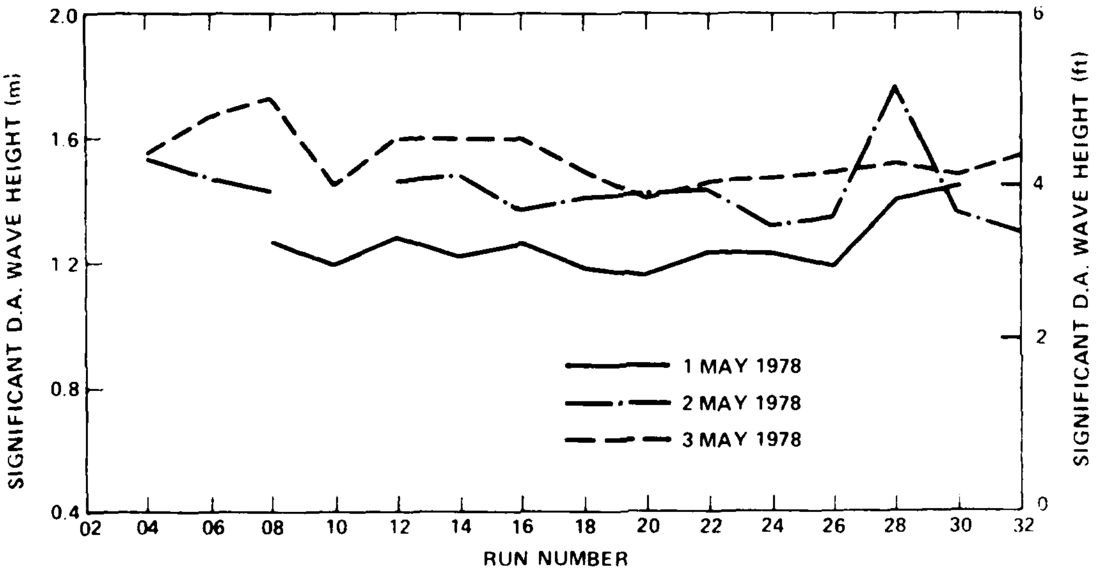


Figure 15 - Significant Wave Height Measured during Trials
1 through 3 May 1978

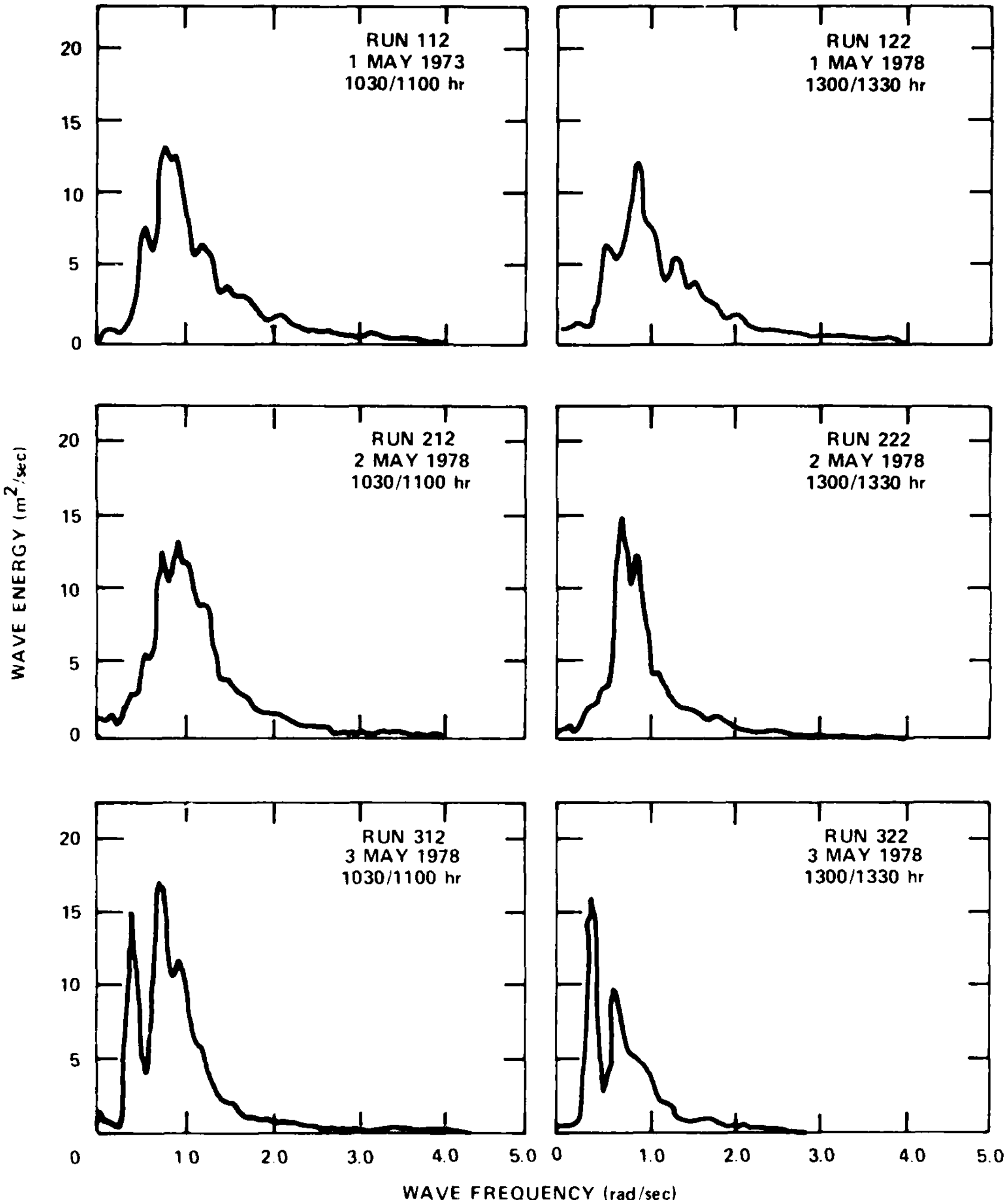


Figure 16 - Representative Wave Spectra Obtained during Trials of 1 through 3 May 1978

TABLE 1 - MELLON SHIP MOTION RECORDER

Manufacturer: Honeywell			Model: 101		Tape Speed: 1-7/8 Inches per Second		
Channel	Measurement	Type	Transducer Manufacturer	Model	Type	Preconditioner Manufacturer	Model
1	Roll Angle	Gyro	Sperry	Mk 19 Mod 3C	Synchro/DC Conv	Astro Sys.	3000
2	Pitch Angle	Gyro	Sperry	Mk 19 Mod 3C	Synchro/DC Conv	Astro Sys.	3000
3*	Heave Acceleration	Accelerometer	Donner	4310 (0.5 g)	Driver Amplifier	Endevco Dana	4470 2820
4	Wave Height	Buoy	Datawell	Wave Rider	Receiver Amplifier	Datawell Dana	WAREP 2820
5	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-
8	Duplication of Channel 1						
9	Duplication of Channel 2						
10*	Duplication of Channel 3						
11	Duplication of Channel 4						
12	-	-	-	-	-	-	-
13	Mode	Power Supply	Trygon	HR 40-750		- None -	
14	Time Code	IRIG-B	Systron-Donner	8152		- None -	

*Deleted after test period completed for 2 May 1978.

TABLE 2 - MELLON HUMAN FACTORS RECORDER

Manufacturer: Honeywell			Model: 101		Tape Speed: 1-7/8 Inches per Second		
Channel	Measurement	Type	Transducer Manufacturer	Model	Type	Preconditioner Manufacturer	Model
1*	Lateral Acceleration	Accelerometer	Donner	4310 (0.5 g)	Driver Amplifier	Endevco Dana	4470 2820
2*	Vertical Acceleration	Accelerometer	Donner	4310 (0.5 g)	Driver Amplifier	Endevco Dana	4470 2820
3*	Longitudinal Acceleration	Accelerometer	Donner	4310 (0.5 g)	Driver Amplifier	Endevco Dana	4470 2820
4	EKG-A	Electrode	Beckman		Amplifier	Honeywell	122-1
5	EKG-B	Electrode	Beckman		Amplifier	Honeywell	122-1
6	Mode	Power Supply	Trygon	HR 40-750		- None -	
7	EKG-D	Electrode	Beckman		Amplifier	Honeywell	122-1
8	EKG-E	Electrode	Beckman		Amplifier	Honeywell	122-1
9	EKG-F	Electrode	Beckman		Amplifier	Honeywell	122-1
10	Events A and B	See Appendix A					
11	Events C and D	See Appendix A					
12	Events E and F	See Appendix A					
13	EKG-C	Electrode	Beckman		Amplifier	Honeywell	122-1
14	Time Code	IRIG-B	Systron-Donner	8152		- None -	

*Deleted after test period completed for 3 May 1978.

TABLE 3 - CAPE CORWIN SHIP MOTION RECORDER

Manufacturer: Honeywell			Model: 101		Tape Speed: 1-7/8 Inches per Second		
Channel	Measurement	Type	Transducer Manufacturer	Model	Type	Preconditioner Manufacturer	Model
1	Roll Angle	Stable Platform	BUSHIPS	Mk I, Mod 0	Potentiometer	DTNSRDC	419-1A
2	Pitch Angle	Stable Platform	BUSHIPS	Mk I, Mod 0	Potentiometer	DTNSRDC	419-1A
3	-	-	-	-	-	-	-
4*	Roll Angle	Gyro	Honeywell	JG-7044A56	Potentiometer	DTNSRDC	419-1A
5*	Pitch Angle	Gyro	Honeywell	JG-7044A56	Potentiometer	DTNSRDC	419-1A
6	Mode	Cal. Box	DTNSRDC			- None -	
7	Heave Acceleration	Accelerometer	Donner	4310 (0.5 g)	Accelerometer	DTNSRDC	415-1A
8**	Lateral Acceleration	Accelerometer	Donner	4310 (1 g)	Accelerometer	DTNSRDC	415-1A
9**	Vertical Acceleration	Accelerometer	Donner	4310 (1 g)	Accelerometer	DTNSRDC	415-1A
10**	Longitudinal Acceleration	Accelerometer	Donner	4310 (1 g)	Accelerometer	DTNSRDC	415-1A
11	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-
14	Time Code	IRIG-B	Systron-Donner	8152		- None -	

*Removed on 5 May 1978--reinstalled 6 May 1978.

**Recorded on 5 May 1978 only.

TABLE 4 - CAPE CORWIN HUMAN FACTORS RECORDER

Manufacturer: Honeywell			Model: 101		Tape Speed: 1-7/8 Inches per Second		
Channel	Measurement	Type	Transducer Manufacturer	Model	Type	Preconditioner Manufacturer	Model
1	Lateral Acceleration	Accelerometer	Donner	4310 (1 g)	Accelerometer	DTNSRDC	415-1A
2	Vertical Acceleration	Accelerometer	Donner	4310 (1 g)	Accelerometer	DTNSRDC	415-1A
3	Longitudinal Acceleration	Accelerometer	Donner	4310 (1 g)	Accelerometer	DTNSRDC	415-1A
4	EKG-A	Electrode	Beckman		Amplifier	Honeywell	122-1
5	EKG-B	Electrode	Beckman		Amplifier	Honeywell	122-1
6	EKG-C	Electrode	Beckman		Amplifier	Honeywell	122-1
7	EKG-D	Electrode	Beckman		Amplifier	Honeywell	122-1
8	EKG-E	Electrode	Beckman		Amplifier	Honeywell	122-1
9	EKG-F	Electrode	Beckman		Amplifier	Honeywell	122-1
10	Events A and B	See Appendix A					
11	Events C and D	See Appendix A					
12	Events E and F	See Appendix A					
13	Mode	Cal. Box	DTNSRDC			- None -	
14	Time Code	IRIG-B	Systron-Donner	8152		- None -	

TABLE 5 - KAIMALINO SHIP MOTION RECORDER

Manufacturer: Ampex			Model: 1300		Tape Speed: 1-7/8 Inches per Second		
Channel	Measurement	Type	Transducer Manufacturer	Model	Type	Preconditioner Manufacturer	Model
1	-	-	-	-	-	-	-
2	Pitch Angle						
3*	Heave Acceleration	Accelerometer	Donner	4310 (1 g)	Accelerometer	DTNSRDC	415-1A
4	Mode	Cal. Box	DTNSRDC			- None -	
5	Roll Angle						
6	-	-	-	-	-	-	-
7	Wave Height	Buoy	Datawell	Wave Rider	Receiver Amplifier	O.S.I. Dana	4523 2820
8	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-
10	Port Canard Angle	Potentiometer			Amplifier	Dana	2820
11	Starboard Canard Angle	Potentiometer			Amplifier	Dana	2820
12	Port Flap Angle	Potentiometer			Amplifier	Dana	2820
13	Starboard Flap Angle	Potentiometer			Amplifier	Dana	2820
14	Time Code	IRIG-B	Systron-Donner	8350		- None -	

*Replaced with vertical acceleration for all runs after 2 May 1978.

TABLE 6 - KAIMALINO HUMAN FACTORS RECORDER

Manufacturer: Honeywell			Model: 101		Tape Speed: 1-7/8 Inches per Second		
Channel	Measurement	Type	Transducer Manufacturer	Model	Type	Preconditioner Manufacturer	Model
1	Lateral Acceleration	Accelerometer	Donner	4310 (0.5 g)	Accelerometer	DTNSRDC	415-1A
2*	Vertical Acceleration	Accelerometer	Donner	4310 (1 g)	Accelerometer	DTNSRDC	415-1A
3	Longitudinal Acceleration	Accelerometer	Donner	4310 (0.5 g)	Accelerometer	DTNSRDC	415-1A
4	EKG-A	Electrode	Beckman		Amplifier	Dana	2820
5	EKG-B	Electrode	Beckman		Amplifier	Dana	2820
6	EKG-C	Electrode	Beckman		Amplifier	Dana	2820
7	EKG-D	Electrode	Beckman		Amplifier	Dana	2820
8	EKG-E	Electrode	Beckman		Amplifier	Dana	2820
9	EKG-F	Electrode	Beckman		Amplifier	Dana	2820
10	Events A and B	See Appendix A					
11	Events C and D	See Appendix A					
12	Events E and F	See Appendix A					
13	Mode	Cal. Box	DTNSRDC			- None -	
14	Time Code	IRIG-B	Systron-Donner	8350		- None -	

*Deleted from 3 May 1978 to 6 May 1978 inclusive.

TABLE 7 - TRANSDUCER LOCATION AND POLARITIES ABOARD MELLON

1.	Cabin Lat. Acc.	Human Factor Room	Acc. to Port	(+)
2.	Cabin Vert. Acc.	Human Factor Room	Acc. Up	(+)
3.	Cabin Long. Acc.	Human Factor Room	Acc. Aft	(+)
4.	Heave Acc.	Oceanographic Winch	Acc. Dn.	(+)
5.	Roll	Ship's Gyro. Room	Stb. Dn.	(+)
6.	Pitch	Ship's Gyro. Room	Bow Up	(+)

NOTE:
Main instrument location in winch room.

TABLE 8 - TRANSDUCER LOCATION AND POLARITIES ABOARD CAPE CORWIN

1.	Cabin Lat. Acc.	Human Factor Room	Acc. to Port	(+)
2.	Cabin Ver. Acc.	Human Factor Room	Acc. Up	(+)
3.	Cabin Long. Acc.	Human Factor Room	Acc. Aft	(+)
4.	Heave Acc.	Engine Room, Air Intake Chamber	Acc. Up	(+)
5.	Roll Stable Table	Engine Room, Air Intake Chamber	Stb. Up	(+)
6.	Pitch Stable Table	Engine Room, Air Intake Chamber	Bow Dn.	(+)
7.	Roll Gyro.	Forward Crew Berthing Area	Stb. Up	(+)
8.	Pitch Gyro.	Forward Crew Berthing Area	Bow Dn.	(+)

NOTE:
Main instrument location in crew's berthing area.

TABLE 9 - TRANSDUCER LOCATIONS AND POLARITIES
ABOARD KAIMALINO

1.	Cabin Lat. Acc.	Human Factor Room	Acc. to Port	(+)
2.	Cabin Vert. Acc.	Human Factor Room	Acc. Up	(+)
3.	Cabin Long. Acc.	Human Factor Room	Acc. Fwd.	(+)
4.	Heave Acc.	Human Factor Room	Acc. Up	(+)
5.	Roll Stable Table	Pilothouse	Stb. Dn.	(+)
6.	Pitch Stable Table	Pilothouse	Bow Up	(+)

NOTE:
Main instrument location starboard passageway forward of machine shop.

TABLE 10 - RUN NUMBER CODING SYSTEM

Ship Motions and Human Factors Data

Run Number 1 3 08

- 08 — Run Start Time
- 3 — Calendar Date
- 1 — Ship Type

Wave Height

Run Number 1 06

- 06 — Run Start Time
- 1 — Calendar Date

Ship Type	Calendar Date	Run Start Time
1 - MELLON	9 - 29 April 1978	02 - 0800 Hours
2 - CAPE CORWIN	0 - 30 April 1978	04 - 0830 Hours
3 - KAIMALINO	1 - 1 May 1978	06 - 0900 Hours
	2 - 2 May 1978	08 - 0930 Hours
	3 - 3 May 1978	10 - 1000 Hours
	4 - 4 May 1978	12 - 1030 Hours
	7 - 7 May 1978	14 - 1100 Hours
	8 - 8 May 1978	16 - 1130 Hours
		18 - 1200 Hours
		20 - 1230 Hours
		22 - 1300 Hours
		24 - 1330 Hours
		26 - 1400 Hours
		28 - 1430 Hours
		30 - 1500 Hours
		32 - 1530 Hours

APPENDIX A

HUMAN FACTORS DATA COLLECTION

by

Steven H. McGuigan

TIME AND TONE TESTS

For the human factors time test and tone test, it was necessary to record the state of three push buttons on each of the six subjects event boxes on each vessel. To record each as a separate analog channel would have required additional tape decks which were not readily available. For this reason it was decided to encode the buttons from two subjects into a single channel. This would allow the 18 buttons from the six subjects of each vessel to be encoded into three channels.

The encoding was done in a digital fashion so that the data were no longer continuous but sampled at discrete points in time. The encoded output consisted of a number of pulses every sample period. This number of pulses was arrived at by treating the data from the six buttons as a binary number and adding one. Thus, with no button pushed one pulse occurs every sample period and with all six buttons pushed there are $(2^6-1) + 1 = 64$ pulses every sample period. The additional pulse is to ensure that at least one pulse is always recorded to facilitate decoding the no button pushed condition.

For decoding, a method of synchronizing on the sample period must be provided. This was done by leaving a gap between sample periods where no pulses could be produced. By making the sample period the equivalent of 80 pulses long, a period of no pulse output of at least 16 pulse lengths is guaranteed since the longest number of output pulses is 64. The end of a sample period is then indicated by the end of a pulse train, the next dummy pulse, explained above, indicating the start of the next sample period.

The pulse rate chosen for encoding was 100 hertz, making the sample period 80/100 = 0.8 seconds. This rate ensured reliable recording of the output on analog tape. Data were played back during analysis at 16 times real time to shorten the analysis time; therefore, values of components in decode circuitry reflect the higher rate.

DETAILS OF CIRCUIT OPERATION

Each vessel had one encoder box with six Winchester connectors on it, one for each subject's button box, and three BNC connector outputs. Housed in the encoder box were four circuit boards, a clock board, and three encoder boards. The clock board provided a common clock and synchronizing signals to the three encoder boards. Each of the three encoder boards took data from six buttons from two subjects and encoded it onto a single output.

The clock board is shown in Figure A.1. The IC1 is a 555 timer IC set up as an adjustable multivibrator with a frequency of 100 hertz, adjustable with P1. The output is available to the encoder boards as CLK and also goes to a counter composed of IC1 and IC2. The counter is loaded with 80 and counts down on every clock pulse. Upon reaching 0, borrow is generated out of IC3. Both R2 and C2 delay this pulse slightly and the output of IC4b then sets the load-enable flip flop composed of IC6a and IC6b and also provides an output on load lines 1 to 3. Three outputs are used here to increase the output drive capacity for use on the encoder boards. The IC4b output is also routed back to the counter which reloads it with 80 for the next sample period. As the clock goes high for the next pulse an output is now produced at the LRST 1 to 3 lines since the load-enable flip flop is set. The output of IC7d is used to clear the flip flop disabling LRST until the next sample period. The filter composed of R3 and C3 is used to lengthen the pulse appearing on the LRST lines.

Figure A.2 shows one of the three encoder boards and the two button boxes that it encodes. Logic gates IC4, IC5, and IC6 are set up as six set-clear flip flops, one for each button input. The normally closed push buttons hold the set inputs of each flip flop in the high state. When a button is depressed, one of the resistors R2, R3, R4, R5, R6, or R7 pulls the associated flip flop set input to ground, setting the flip flop. At the end of a sample period the clock board first generates a pulse on Load which causes the state of the six flip flops to be loaded into the counter composed of IC2 and IC3. The clock board then generates a pulse on LRST Ø which resets all the flip flops.

The counters loaded with data from the flip flops decrement one count during each clock pulse on CLK. In addition to decrementing the counter, each pulse is also fed to the output through T1 and T2. Potentiometer P1 provides for adjusting the output level, and T1 and T2 prevent loading of P1 and provide good drive capability on the output. Upon decrementing to zero the counter generates borrow, clearing the enable flip flop through IC1a, and preventing anymore clock pulses passing through IC1d and appearing on the output. As the sample period ends, the clock board again generates Load followed by LRST in preparation for the next sample period.

The decoder board is shown in Figure A.3. This board was used to decode the button box data from tape for data analysis. A playback speed of 16 times real time was used during analysis and component values reflect the increased data rate.

The input from tape is applied to amplified IC1; P1 is used to adjust the level to approximately 5 volts; and IC2 is a low pass filter to attenuate tape noise. The output of the filter is fed to a hysteresis comparator composed of IC3, IC4, and IC5. Then P2 and P3 are used to set the trip points for the comparator. The output of IC5b is a transistor-transistor logic (TTL) version of the input pulses and is applied to the countup input of a counter composed of IC8 and IC9. The counter is started at an initial value of -1 so that the additional pulse that was added during encoding is, in essence, subtracted. During the sample period, the counter increments at each pulse. As the pulses stop, the output of IC5b is left in a high state. The output of IC5d then is low and transistor T1 is in the off state allowing C3 to change through P4. When the voltage on C3 reaches approximately 3.3 volts, IC6 is triggered and produces a negative going output on pin 3. This is fed to IC7, a 74123 dual monostable multivibrator which produces two outputs, Load1 and Latch1. Latch1 occurs first and is used to latch the output of the counter in latches IC10 and IC11. Load1 then resets the counters back to -1 in preparation for the next sample.

The first pulse of the next sample will turn T1 on and discharge C3 resetting the output of IC6. As long as pulses continue, C3 does not have sufficient time to change to 3.3 volts and no output is produced at pin 3 of IC6.

ELECTROCARDIOGRAM DETECTOR (EKG)

Figure A.4 shows the EKG detector used to take the analog EKG signals from tape and convert them to digital form, compatible with digital computer inputs. Again a playback speed 16 times real time was used so circuit values reflect this. Both C1 and R1 form a high-pass filter that prevents preamp IC1 from saturating due to direct current offsets in the signal. Low frequency components in the EKG signal including the P and the T waves are attenuated by a Chebyshev high-pass filter IC2 and IC3. Frequency components of the R wave are high enough to pass through the filter. It is these R waves which were used in the processing of the EKG data; the remainder of the signal being neglected. High frequency noise, sometimes found on the signal, is attenuated in R8 and C6 but the cutoff frequency here is high enough to allow the R wave to pass. Potentiometer P1, in conjunction with IC4, is used to adjust the signal level for optimum detection. The EKG signals from different subjects were seen to have different polarities and in some instances polarities changed on a given subject after a break period. These reversals were caused by a reversal of two of the three color coded EKG sensor leads upon reconnection after the break period. This polarity reversal is, thus, indicative of an error on the subjects behalf while performing this task. To contend with this, IC5 and IC6 form an absolute value circuit. The output of IC6 should contain positive going R waves. Capacitor C8 detects the noise envelope of the signal whereas C7 detects the envelope of the R wave. Diode D5 prevents C8 from responding to the R wave portion of the signal. Amplifier IC9 takes the difference of these signals so that the circuit now responds only to R wave signals exceeding the noise envelope by set amounts. This improves detection in noisy areas and also prevents (when adjusted correctly) the circuit from triggering on transmitter induced noise found on some tapes. Amplifiers IC10, IC11, and IC12 form an adjustable hysteresis comparator with P2 and P3 used to adjust upper and lower trip points. This facilitates adjusting the amount the R wave must exceed the noise envelope to constitute a pulse detection. Latch IC13 is a one shot, set for a pulse width equivalent to a pulse rate of 200 beats per minute. The one shot prevents double peaks in the R wave (caused by filter and absolute value circuits) from producing more than one output per pulse.

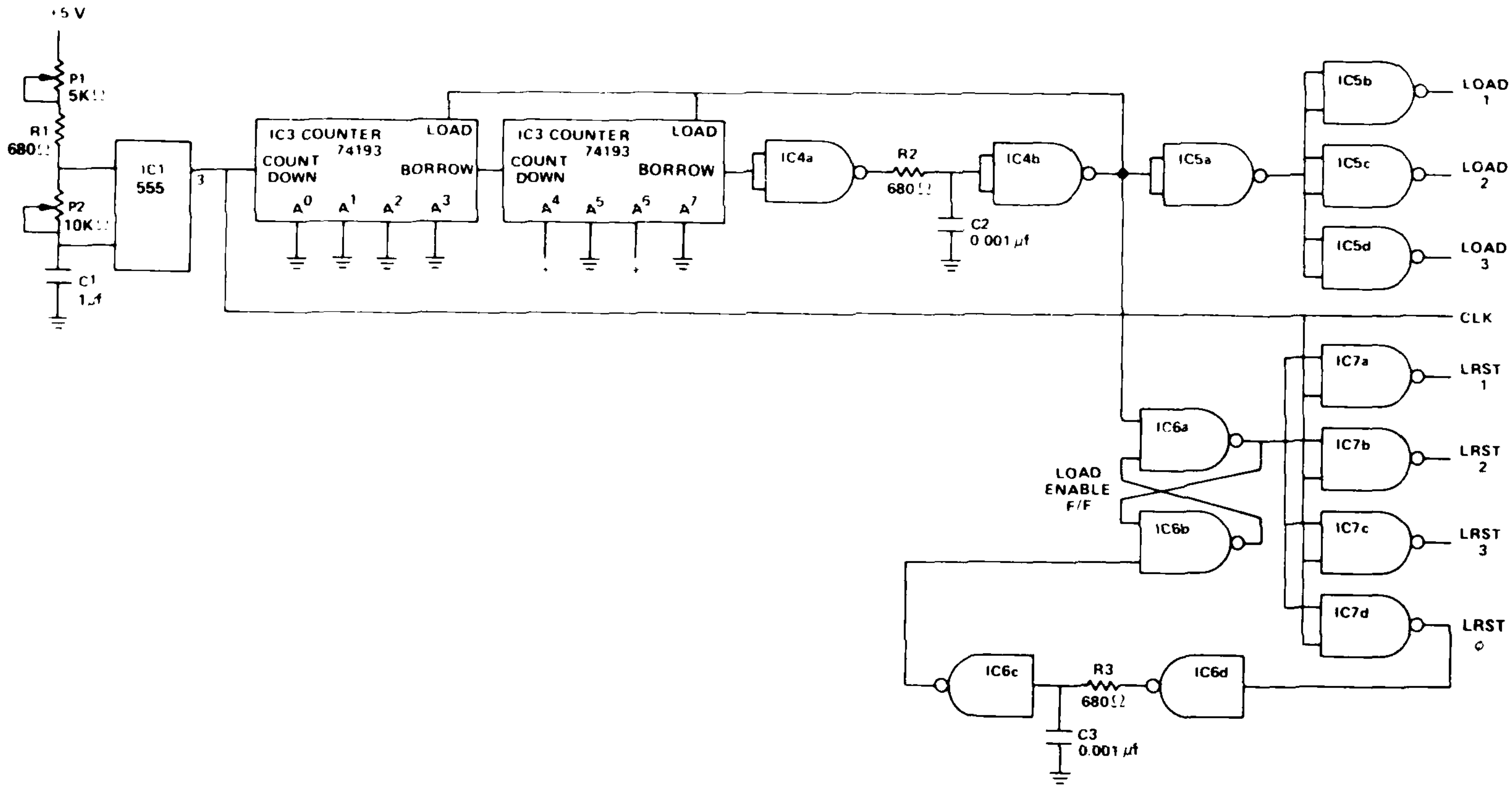


Figure A.1 - Button Encoder--Clock Board

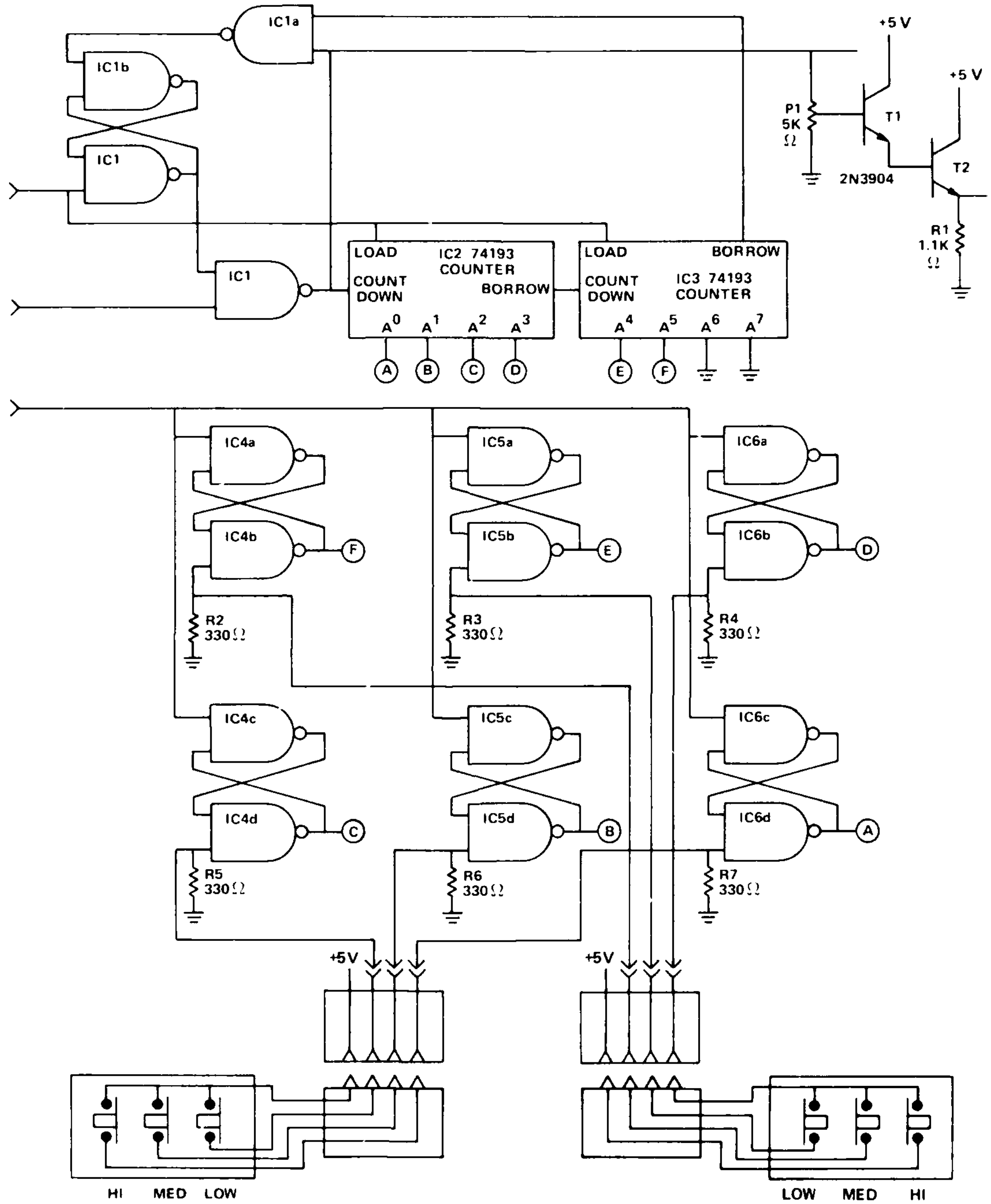


Figure A.2 - Button Encoder--Encoder Board

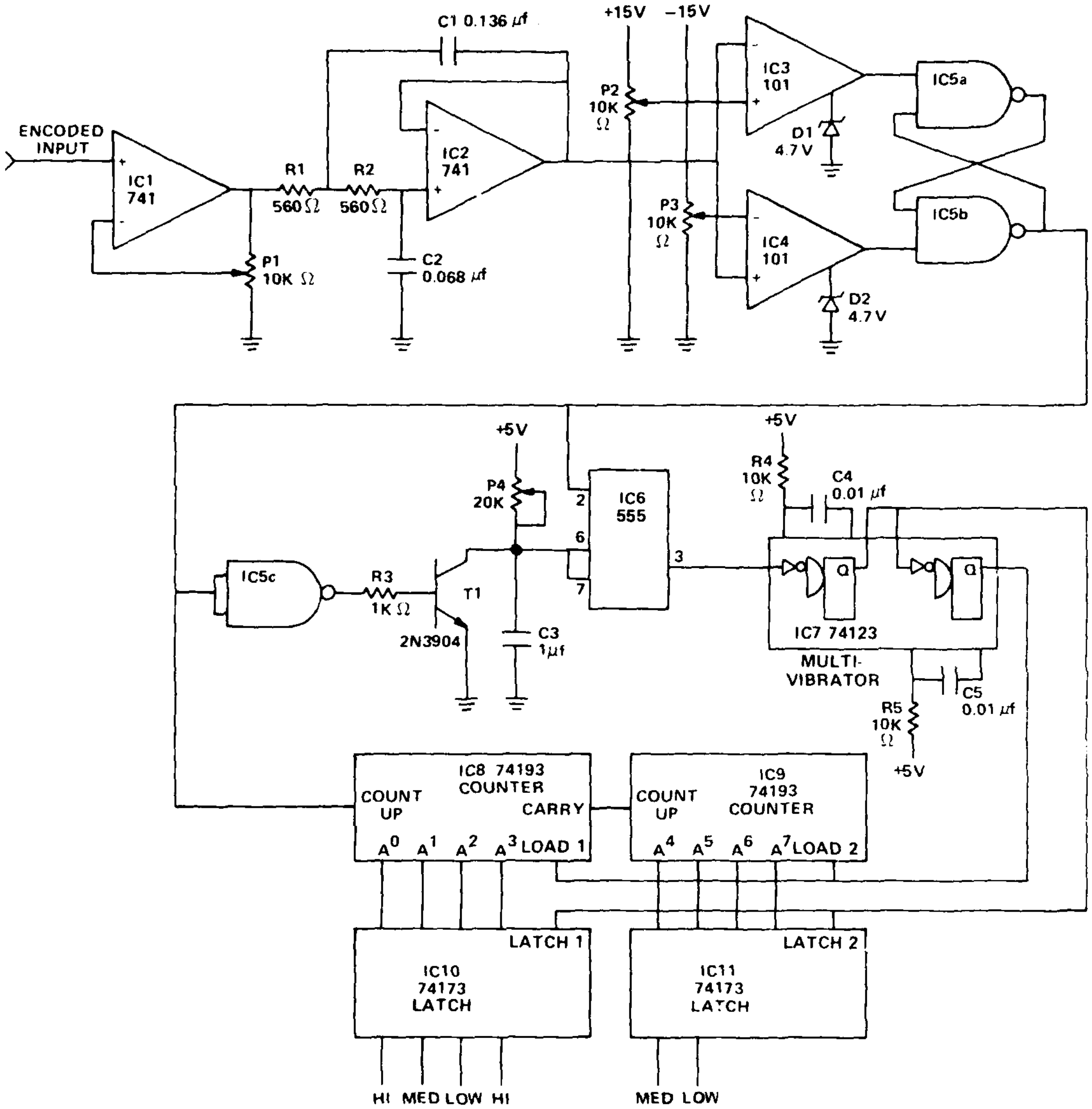


Figure A.3 - Button Decoder

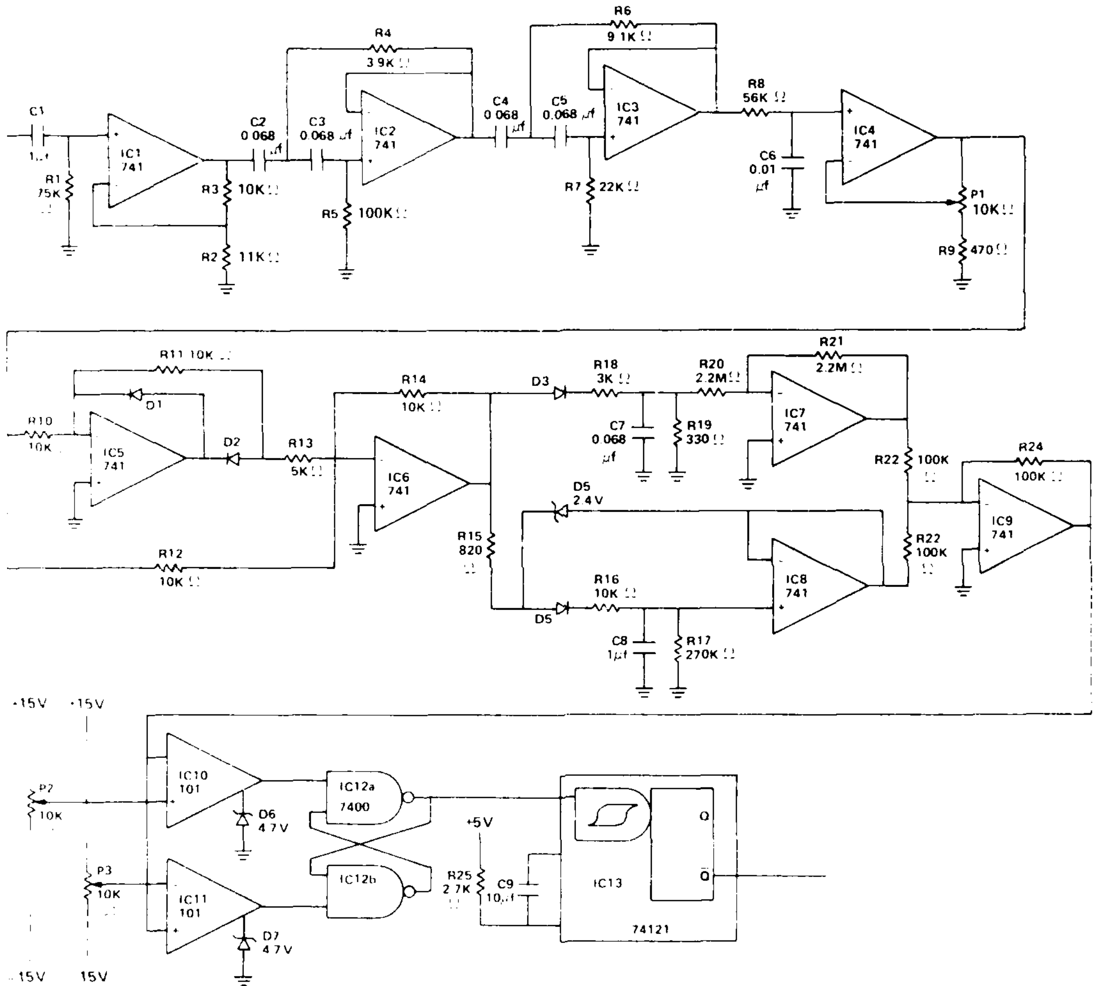


Figure A.4 - Electrocardiogram Detector

APPENDIX B

GENERAL DISCUSSION OF DATA COLLECTION

Data for a particular measurement are generally recorded on a frequency modulated (FM) magnetic tape recorder. This record of the data signal is analogous to a continuous tracing of the signal in time; hence, it is often called an analog recording. Recorded data are usually processed with the aid of a digital computer which allows more sophisticated analyses to be performed in less time than if the analysis were done by hand. Unfortunately, the digital computer cannot accept a continuous signal for processing but requires discrete values, or digits; hence the name "digital" computer. In order to provide these discrete values; the original analog recording is sampled at various times and the value of the signal at each point in time is recorded as a discrete number. Figure B.1 presents an analog signal which has been sampled every 't' units of time. The value of the signal at each sample, shown as a black dot, is now recorded on another magnetic tape which is called a digital tape. This process of sampling an analog tape to obtain digital values is known as digitizing or going A to D (analog to digital). It is similar to recording a continuous motion on movie film and, like the movie, the quality of the recording is dependent on the number of samples, or frames, taken in a given unit of time. Figure B.1 has a sample rate which provides approximately 10 sample points for each cycle of the data signal. The sample rate which is used for any given signal is a function of several variables such as signal frequency, noise frequency, length of analysis time, A to D speed or memory restrictions, etc. Once this digitizing process has been completed the digital tape contains a listing or table of data values which are referenced to some arbitrary value. Figure B.1 depicts such a reference line and attendant data point values in the lower right-hand corner. In the case of ship motions, this reference value may be true vertical or horizontal, true course, desired speed, etc. or it may have no physical meaning as we shall see.

Preceding Page Blank - Not Filmed

Generally the first step in any analysis scheme is to determine the mean or average value (μ) of the data signal. This is done by adding all of the sample values together and dividing by the number of total samples. The outcome of this procedure is the mean value which is shown in Figure B.1 as the horizontal line running through the data signal. Now, to somewhat simplify further calculations, the mean value is subtracted from each of the sample point values. In this manner the value now attached to each sample point represents its distance from the mean. By noting the actual mean value we can now treat the signal as if the mean were zero, or perhaps a more useful expression of the same idea is that we now assume that the mean value falls directly upon the reference value. Naturally, we can at any time add the actual mean value back in should we wish to since this adding and subtracting of the mean value is merely a shifting of the signal with respect to the reference value.

Before proceeding to a discussion of the amplitude values, it is instructive to define the root mean square (RMS) of the data sample values and look at some of its properties. The RMS is found by taking the square root of the sum of the squares divided by the number of samples of all the sample points. This value is very useful in statistics and is generally given the symbol σ. Since most physical phenomenon follow basic laws, exhibit certain similarities, and repeat various patterns; statisticians group similar phenomena into specific types called processes. Most ship motions have data point distributions which obey the normal or Gaussian process. Figure B.2 presents a sketch of the probability density for the Gaussian process. Note that the curve is centered on the mean value, μ, and is symmetric about it. Note also that the curve is defined completely by the values of μ and σ; the mean and RMS. Let us look at what Figure B.2 shows us about our data. The curve peaks at the mean value μ indicating that the sample values tend to cluster about the mean value. The curve is symmetric about μ, indicating that as many values fall above μ as below. For this reason the mean or average is identical to the median which is defined as that value having as many samples above it as below it. By consulting tables compiled for the Gaussian distribution, we learn that approximately 68 percent of all sample values will be within σ of the mean while fewer than 5 percent will be more than 2σ away from the mean. We also see that if σ is very small, the sample values will be very close to μ while if σ is very large the samples will tend to be more spread out.

While the sample values are of interest, it is generally more useful to define the excursions and double amplitudes which occur within the data. Excursions, or single amplitudes, are labeled A-1, A-2, etc. in Figure B.1 while double amplitudes are labeled D-1, D-2, etc. As may be seen in Figure B.1, excursions are generally measured from the mean value and may lie above or below it. For convenience, a positive value is generally assigned to excursions in one direction while excursions to the other side are referred to as negative. In practice, the values of the excursions are identified by a digital computer using the listing of sample values found on the digital tape. The faithfulness with which the sample point represents the actual signal excursion is dependent upon the sample rate. The more samples taken the better the actual signal is defined. In the example of Figure B.1, using a sample rate which yields only 10 points per data cycle, we see that only amplitude A-8 misses being representative of the actual excursion value of the signal. Obviously, a sample rate 10 times higher, yielding 100 samples per cycle, would represent the wave form shown more completely.

Double amplitudes are found by pairing consecutive single amplitudes and adding them algebraically. Thus, in Figure B.1, we find that D-1 is the sum of A-2 and A-3. We may note that while the values we obtain for the excursions are not dependent on the order in which we evaluate them, the values obtained for the double amplitudes are. That is, if we define D-1 as being the sum of A-1 and A-2, instead of A-2 and A-3, we not only change its value but the values of all following double amplitudes since D-2 is now the sum of A-3 and A-4, etc. How do we rectify this apparent disagreement in values? The answer lies in the statistical properties of the data. When we speak of the signal from a statistical viewpoint, it is immaterial how we started defining the double amplitude values because, in time, all statistical values such as the mean and RMS will not depend on how the consecutive excursions were paired. The key word here is "time." For short signal lengths, the order of the pairing will make a difference which correctly implies that the quality of the statistical parameters obtained from a given data signal sample is dependent on the length of that sample. Hence, it is important to know what the nature of the data being taken is before actually recording it so that an adequate sample time can be defined.

In practice, most analysis schemes define a cycle as that amount of data lying within three consecutive mean crossings; the two excursions which occur in that cycle are defined as the most positive and most negative sample data values within the cycle, and the double amplitude value is the sum of the excursions. The analysis routine may always use the first positive to negative crossing as a starting point, or it may just use the first crossing it encounters. Just as average and RMS values were calculated for the sample data points, so too are these values computed for the excursion or double amplitude values.

Amplitude values for most ship motions and also for wave height are not, however, defined by a normal or Gaussian process as was the case for the data sample point values. The probability density function for single amplitude values is shown in Figure B.3 and is known alternately as the circular multivariate normal distribution or as the Rayleigh distribution. Since positive and negative excursions are equally probable, Figure B.3 is based on the magnitudes of the excursions and does not consider their signs. The probability distribution function for double amplitudes would be identical in shape and could be constructed by doubling the values found on the horizontal axis. Thus, the probability of realizing any given double amplitude value is exactly the same as the probability of realizing a single amplitude value one-half as large.

Note that this distribution function is not symmetrical and that the mean and median are not equivalent. By consulting statistical tables which apply to this function, we find that approximately 60 percent of all single amplitude values are larger than σ, 15 percent are larger than 2σ, and 1 percent are larger than 3σ. The average, or median, value is about 1.25σ, as seen in Figure B.3. We may also note that the distribution peak occurs at a value equal to σ indicating that σ is the most probable, or mode, value.

Now that we have seen how a typical analysis routine works and what an RMS and mean value indicate, let us briefly review what all this means to the user.

First, we have taken real world actual data and defined the data sample point values for average, maximum, and RMS. These values are truely indicative of the actual data recorded. We have also defined either single amplitude or double amplitude values, again based on the actual data sample. The choice as to whether one presents single or double amplitude data is generally based on convention since, statistically, they are equivalent. However, from the actual viewpoint, each has its own information to impart. Single amplitude analysis will provide the values of the five (arbitrarily) largest excursions found within the data sample. While the sense, or sign, of these values will be given, their location in time is generally not given. Hence, one cannot add the largest positive to the largest negative and assume that the result is the largest double amplitude within the sample. Similar comments apply to double amplitude analysis. The five largest double amplitudes are presented; however, information about the excursions which they consist of is lost.

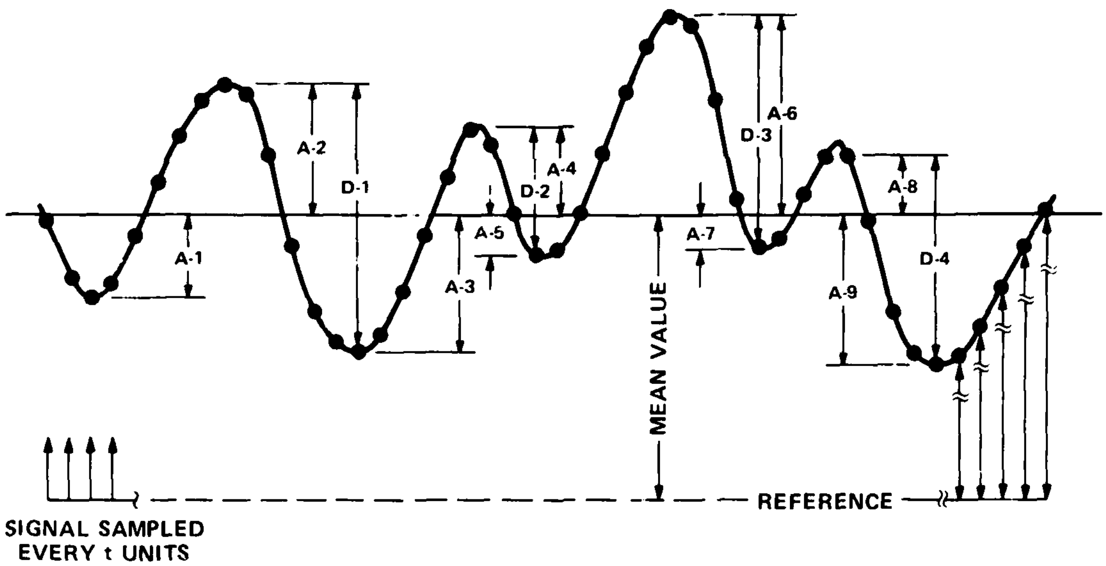


Figure B.1 - Sample Wave Form

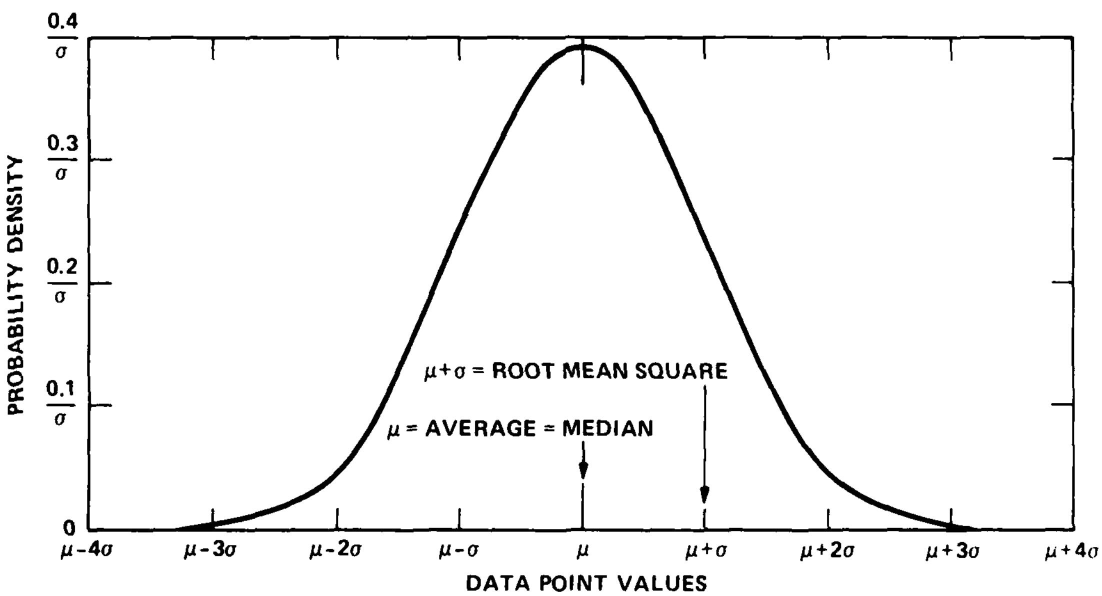


Figure B.2 - Gaussian Distribution

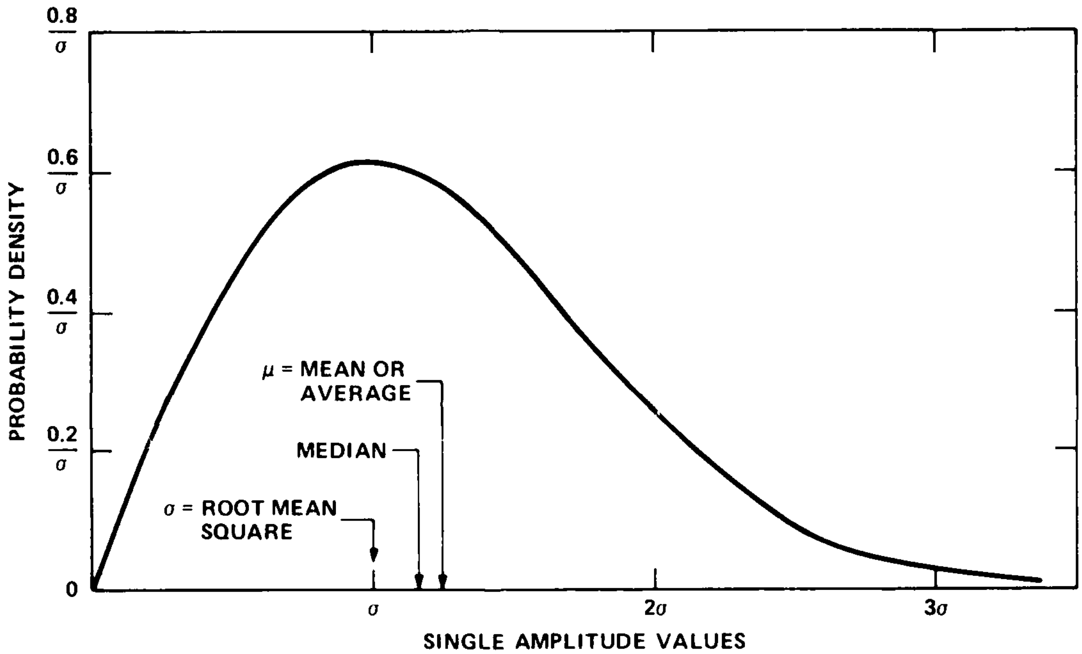


Figure B.3 - Rayleigh Distribution

APPENDIX C

SHIP MOTIONS, ACCELERATIONS, AND WAVE HEIGHT ANALYSIS FORMAT

This appendix describes the format and defines the terms used on the analysis output contained on microfiche* numbers 1 through 11. The information on fiche number 7 (wave height) is indexed using only a three digit run number rather than four--the first digit, which represents ship type, being deleted. For those data which were not analyzed fully (phase 1 analysis only), the definitions are also as given below; however, the output contains only the first page. Data regarding turns are contained after the main data.

Tabular data consisting of an initial summary sheet, a spectral summary sheet, a listing of spectral data points, a histogram summary sheet, tabular histograms, and spectral and histogram graphics are presented for each parameter.

The initial summary sheet contains, in order left to right, top to bottom, the following items. (MELLON ship motions for 0800 hours on 3 May 1978 are used as the example.)

1. AVG & STDV RUNS 1302-1302: Average and standard deviation for the grouping of runs from Run 1302 through 1302, i.e., Run 1302 only
2. PRELIMINARY DATA: Nature of data
3. MELLON: Vessel name
4. USCG SIDE-BY-SIDE SHIP TRIALS - HAWAII: Trial name
5. 3 MAY 1978: Date data recorded
6. SHIP MOTION MEASUREMENTS: Data type
7. OCTAGONAL CIRCUIT: Proposed trial location
8. RUDDER ROLL STABILIZER SYSTEM SECURED: Special ship condition, if any
9. HEADING = 180.0 DEG: Ship relative heading in degrees
10. NOMIN SPEED = 7.00 KNOTS: Ship nominal speed in knots

*Enclosed is a set of 13 microfiche at 48X magnification. Available upon request is a set of microfiche (for better quality printing) at 24X magnification.

Preceding Page Blank

11. RUNS:1302: Run Number

12. 0.000-1184.0: Analysis starts at 0.0 seconds and ends at 1184.0 seconds into the run

13. TOTAL TIME:1184.0 SEC: Total run time in seconds

14. CHAN: Column listing the parameter names

15. MEAN: Column listing algebraic mean of all data points

16. STD DEV: Column listing the standard deviation. (The root of the average of the squares of the differences from their mean of the data points)

17. MINIMUM: The most negative data point value

18. MAXIMUM: The most positive data point value

19. 1 ROLL: First parameter - roll angle

20. DEG: Roll motion has units of degrees

21. 3.179E-02: Roll mean in 0.03179 degrees

22. 1.851E+00: Roll standard deviation is 1.851 degrees

23. -6.058E+00: Most negative roll excursion is 6.058 degrees

24. 6.332E+00: Most positive roll excursion is 6.332 degrees

Identical information is then listed for additional parameters. The spectral summary sheet is similar in nature and only those items which need comment will be addressed.

1. SCAN RATE: 7.500/7.50: This data was sampled at 7.5 samples per second and 7.5 samples per second were used in the analysis

2. 64.4 DOF: This data has a degrees of freedom value of 64.4

3. AMP. MAX: Maximum power spectral value

4. FREQ. MAX: Frequency at which amp. max. occurs

5. MOMENTO: 0^{th} spectral moment

   First through fourth moments follow:

6. ROOTMO: The square root of the 0^{th} spectral moment. This value should approximate the standard deviation

7. STD. DEV: As earlier

8. RATIO: Ratio of items 6 and 7. This value should be near unity

9. ROOTMOx4: Four times item 6 (derived significant double amplitude value)

10. AVE. PERIOD: Average period ($2\pi M0/M1$)

11. O-CR PERIOD: Zero crossing period ($2\pi\sqrt{M0/M2}$)

12. BROADNESS: Spectral broadness

13. 1/2 PWR B.W.: The half power bandwidth in radians per second

14. STAT. ERROR: Statistical error associated with power spectra in percent. The listing of spectral data points is straightforward. Note that the dimensional units do not indicate a denominator with units of radians which is understood.

The histogram summary sheet is also straightforward with the following additions:

1. # OF CYCLES: Number of data cycles within the data analyzed
2. # OF DATA PTS: Number of data points within the data analyzed
3. PEAK AVG: The average peak amplitude (referenced to the mean)
4. M2: Second moment
5. SKEW: Skewness
6. KURT: Kurtosis
7. HIGHEST: The largest peak value
8. 2ND: The second largest peak value
9. 1/3 RD: The estimated average of the one-third highest peaks
10. 1/10TH: The estimated average of the $1/10^{th}$ highest peaks

Similar information for the troughs follows on the same printout.

The tabular histograms present the peak and trough analysis in a histogram format. As may be seen, the values recorded during the analysis for the peaks and troughs have been collected into groups by amplitude. Looking at roll in Run 1302, go down the column until you find the value 2.50E-01. This value represents the center of the first grouping (shown as a bar on the graphic histogram). That is, we establish a grouping with a center value of 0.25 degrees; largest value of twice this, or 0.50 degrees, and minimum value 0.0 degrees. Since the values are positive, we are dealing with peaks. Additional groups of values are centered at the other amplitudes shown in this column, i.e., at 0.75, 1.25, 1.75, etc. All groups are 0.5 degrees wide. The "0-R" shown at the extreme end of the peak and/or trough center amplitude listing indicates values "out-of-range"; that is, values numerically larger than those contained in any of the other groups.

The "NO OF ENCR" column indicates the number of peak or trough values found within a given grouping. We see that the group centered at 0.25 degrees has 9 values in it. This indicates that nine peaks were found to have values lying between 0 and 0.5 degrees. Similarly, 12 troughs were found to lie between 0 and -0.5 degrees. The "LESS THAN" and "MORE THAN" columns indicate that a given number of peaks or troughs with values more than or less than those of a given group were found. For example: for the same run (1302 Ship Motions) look at the pitch data. We see the first grouping is centered at 0.15 degrees. Hence each group is 0.30 degrees wide. Look at the grouping of troughs centered at -1.35 degrees. This group has values from -1.20 degrees to -1.50 degrees and we see that 20 trough values in this range were found. Additionally, 112 troughs of less than -1.20 degrees were found and 29 of more than -1.50 degrees were found.

The graphic data are straightforward and need no explanation except that the abscissa which is labeled "OMEGAE" represents the encounter frequency between waves and vessel.

On the evening of 2 May 1978 the transducers which measured vertical acceleration on KAIMALINO and heave on MELLON were transferred to another vessel. Hence the values given in the data for these measurements on 3 May are not to be used. Substitution of vertical acceleration for heave on MELLON is recommended to approximate the heave. Similar substitution of heave for vertical acceleration on KAIMALINO is also recommended to approximate the vertical acceleration.

APPENDIX D
ELECTROCARDIOGRAM ANALYSIS FORMAT

The format used here will be explained using Run 1410, which can be found on fiche number 12, as an example. The heading is self-explanatory giving ship name, trial name and trial date. The run code is the same as that given in Table 10 with one exception; these data were analyzed on an hourly basis except where a tape change occurred on the half-hour during the trial. Hence, it is generally found that run numbers given will increment by 4, thus covering one hour of clock time. Where a tape change was made on the half hour, this analysis will show two run increments of 2, each covering one-half hour of clock time. This should not present difficulties since clock time for all data is given and may be correlated with previous data.

The "Time Code" column gives local clock time at the end of the time period used to obtain the EKG counts which are given under the headings "Sub A" through "Sub F." Electrocardiogram data are always presented as beats per minute. The "Time Interval" column gives the interval time over which the given row of EKG's were based. The "EKG Scans" column provides a correlation between this data and the actual strip chart recordings of the data.

Hence, the first row shows that at 10 hours, zero minutes, and 3 seconds subject A was found to have had a pulse rate of 88 beats per minute based on the last 60 seconds of time. This minute-by-minute processing continues until 10:14:15, at which time the code was either not available or not readable as indicated by the asterisk. When this occurs, the analysis routine uses a backup clock based on pulses obtained from the event boxes, if they are turned on. Thus when a time code entry is followed by an asterisk, the time code entry is <u>not</u> derived from the time code channel but from an alternate source.

The EKG data are now processed using a time interval based on this alternate time source. This is indicated by a shift of the data output to the right, that is, following the slash. The time interval given is based on this alternate source and is also shifted to the right. No data are presented in the normal location since no time code time interval can be determined. A similar instance of faulty time code data follows immediately and is also indicated by an asterisk. At 10:17:03 the time code channel is flagged by a plus (+) sign. This indicates that the time code just printed is taken from the time code channel but that something "abnormal" has occurred within the time interval being processed. For these cases, data based on both the time code channel time interval and on the alternately based time interval are presented. Those values based on the alternate time base are again shifted to the right. A similar situation occurs at 10:42:51. Note that for the time period ending at 10:17:03 the pulse rates based on the alternate source appear to be correct, while for the time period ending at 10:42:51 the pulse rates based on the time code channel appear to be correct. It must be emphasized that both values may be incorrect. Only by returning to the strip chart can one ascertain the correct pulse rate with surety.

Some guidance can be given, however, based on our experience in debugging the analysis routine. A "normal" scan, that is, one which is unflagged, should cover a time interval of 60 seconds and results in data which were found to be quite reliable. However, some isolated cases were found where the pulse rate given did not agree with the strip chart. One such case is the 105 beats per minute given for subject F for the interval ending at 10:10:03. The correct rate is approximately 73 beats per minute.

A "normal" scan based on the event box pulses, as indicated by an asterisk, should cover 72 seconds and was also found to be quite reliable. Where the time code is flagged with a plus sign, and/or where the time intervals are neither 60 nor 72 seconds, the data are suspect since a problem with the recording itself is indicated.

APPENDIX E

TONE TEST AND TIME ESTIMATION ANALYSIS FORMAT

The tone test and time estimation data represent the unchecked output of the analysis program used to extract the time intervals between successive responses of the individual subjects during the tone test and time estimation test. To aid in the explanation of the output format, Run 3002 and Figure E.1, which is appended, will be used.

Referring to the tone test analysis for Run 3002, which is on fiche number 13, we find the standard title information, "run number," "start time," and columns of figures labeled "high," "med.," and "low" for subjects A through F. The run numbering system is the same as that used for the EKG analysis. The "start time" indicates the local clock time at the start of the data analysis for the run--in this case, it is 8 hours, 35 minutes, and 2 seconds. As will become clear later, this time does not correspond to the start of the actual test period but should precede it by approximately 5 minutes. The columnar figures indicate the intervals of successive responses for the individual buttons. Looking at the "high" button column for subject A, we have the following interpretation:

1. The subject depresses the "high" button 354 seconds after the "starr time."
2. The "high" button is again depressed 49 seconds later.
3. Three more button depressions at intervals of 114, 166, and 90 seconds are recorded.
4. No further depressions of this button are recorded during this test.
5. The total number of depressions (5) is recorded at the bottom just beneath the dashed line.

The asterisk following the fifth, seventh, and ninth intervals for the "low" button for subject A indicates that the button was depressed and held down (or very rapidly activated) for a period of greater than approximately 2 seconds at the start of the interval.

Figure E.1 presents a sketch of a typical pulse sequence. Note that each interval starts at the front of a pulse and ends at the front of the next pulse. In this manner, the interval being measured is not dependent on the duration of the actual pulse which starts or ends it. If the pulse duration is greater than approximately 2 seconds, the asterisk is assigned to the interval which contains that pulse (i.e., the start pulse). Relating the results shown in the "high" column for subject A during Run 3002 to Figure E.1 we would have,

I-1 = 354 seconds
I-2 = 49 seconds
etc.

If pulse P-2 were greater than 2 seconds, an asterisk would appear after the 49 given as the duration of Interval I-2, etc.

It should be noted that the interval from the start of the actual tone test (i.e., tape recording of tones turned on) to the first pulse is not recovered by the analysis. This interval is indicated in Figure E.1 by an "X."

The time estimation format is very similar to that found in the Tone Test Analysis, with the tabular numbers indicating the subject's time estimates in seconds. The start time is again the local time at which analysis started and does not correspond to the actual start of the test. Those runs which do not give start times were recovered from data areas within which the time code data were not readable. These runs will require some interpretation by the scorer as they may contain an abnormally long first value. The first actual time estimate by the subject may or may not be contained within this first value. Some runs indicate that the subject has completed the test (shown by all zeros) followed by numerous listing of a 224-second value. These values are to be ignored.

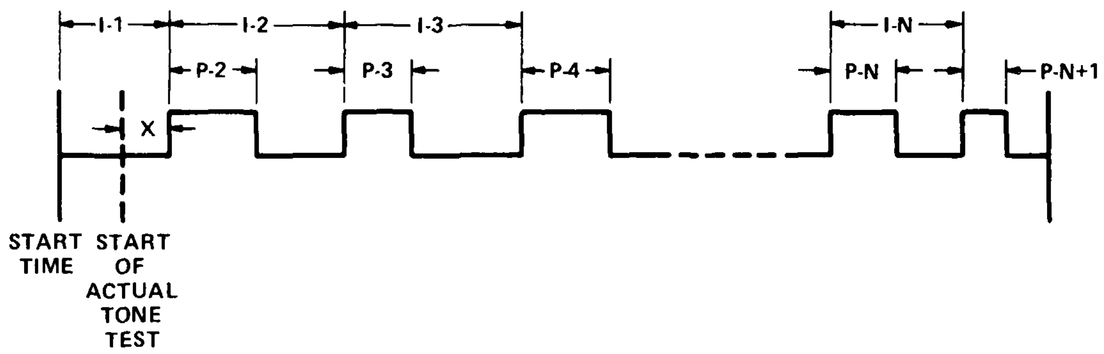


Figure E.1 - Sketch of Typical Pulse Sequence

APPENDIX F

TRIAL ANALYSIS OUTPUT

Trial results are contained on the 13 microfiche (at 48X magnification) enclosed in the packet attached inside the back cover of this report. Table F.1 provides an index to aid in locating specific data. The data within a major section are arranged by run numbers with missing run numbers indicating that data for that run are not available. For purposes of better resolution in printing, microfiche of 24X magnification are available upon request.

TABLE F.1 - MICROFICHE INDEX

Fiche Number	Contents
1	MELLON Ship Motions - Octagon
2	CAPE CORWIN Ship Motions - Octagon
3	KAIMALINO Ship Motion - Octagon
4	MELLON Accelerations - Octagon
5	CAPE CORWIN Accelerations - Octagon and Dockside
6	KAIMALINO Accelerations - Octagon
7	Wave Height - Octagon
8	CAPE CORWIN Ship Motions - 7 and 8 May 1978
9	KAIMALINO Ship Motions - 7 and 8 May 1978
10	CAPE CORWIN Accelerations - 7 and 8 May 1978
11	KAIMALINO Accelerations - 7 and 8 May 1978
12	EKG Analysis
13	Tone Test and Time Estimation

Preceding Page Blank

INITIAL DISTRIBUTION

Copies	
1	ASN (RE&S) P.J. Mantle
1	ONR Code 444
3	NAVMAT 1 MAT 08T, T. Horvath 1 MAT 08T, O.J. Remson 1 MAT 08T23, LCDR Hinton
14	NAVSEA 1 SEA 031, R. Johnson 1 SEA 031, G. Kerr 1 SEA 031, C. Kennel 1 SEA 03R, L. Benen 1 SEA 03R, Dilts 1 SEA 03R, N. Kobitz 1 SEA 03R, J. Schuler 1 SEA 312, P.A. Gale 1 SEA 312, J.W. Kehoe 1 SEA 321, E.N. Comstock 1 SEA 321, R.G. Keane, Jr. 1 SEA 61433, O. White 1 SEA 61433, F. Prout 1 PMS 304-20, CDR J.J. Fee
1	Naval Academy Engineering Dept./Prof. E.V. Lewis
8	NOSC, Hawaii 5 D. Hightown 2 USNS KAIMALINO 1 Dr. R. Pepper
12	DTIC
3	USCG-HQ (R&D) 1 T. Milton 1 D. Walden 1 LCDR K. Williams
2	USCG-HQ, Chief Office of Engineering
1	USCG, 1st District

Copies	
1	USCG, 2nd District
1	USCG, 3rd District
1	USCG, 4th District
1	USCG, 7th District
1	USCG, 8th District
1	USCG, 9th District
1	USCG, 11th District
1	USCG, 12th District
1	USCG, 13th District
7	USCG, 14th District 1 COMMANDER 1 CDR P. Dickerson 1 LT P. Mason 2 USCGC MELLON (WHEC 717) 2 USCGC CAPE CORWIN (WMEC 95326)
1	USCG, 17th District
1	Coast Guard Activities, Europe
1	USCG, Far East Section
2	USCG Academy, NLON
1	USCG, R&D Avery Point
6	DOT, HQ Lib Services Division (M-49)
1	DOT, Research & Special Program Administration (DPA-26)
4	MARAD 1 C. Cherrix 1 M.P. Lasky 1 G. Levine 1 J. Lisnyk

Preceding Page Blank

Copies	
2	MARITIME Research Information Service 1 RADM R. King (retired)
1	Univ. of Calif., Berkeley/ J.R. Paulling, Jr.
3	Univ. of Calif., Berkeley/ TRISNET Repository
1	Univ. of Hawaii/ M. St. Denis
4	MIT 1 5-207/M.S. Triantsfyllou 1 5-226/I. Dyer 1 5-319/M.A. Abkowitz 1 5-323/C. Chryssostomidis
3	Northwestern Univ./TRISNET Repository
3	SIT Davidson Lab. 1 J.F. Dalzell 1 E. Numata 1 D. Savitsky
1	American Bureau of Shipping/ H.H. Chen
1	Boeing Marine Systems/ D.A. Stark
1	Exxon International/ P.F. Weber
1	Continental Oil/ N. Birrell
1	Hoffman Maritime Consultants/D. Hoffman
1	MPR Associates Washington, DC 20036/ F.H. Sellars

Copies	
1	NAMRL Box 29407 New Orleans, LA 70189/ Dr. C.L. Ewing, Director
3	National Transportation Safety Board 1 R.E. Johnson 1 Government Liaison Branch (PP-23) 1 FOB10A (AI-60)
1	Rockwell International/ M. Eckhard
3	Transportation Systems Center

CENTER DISTRIBUTION

Copies	Code	Name
1	012	R.C. Allen
1	11	W.M. Ellsworth
10	111	J. Gore (SWATH Program Office)
1	1151	W.C. O'Neill
10	117	S. Hawkins
1	117	G.R. Lamb, Jr.
1	117	R.M. Stevens
2	15	
1	15	D.S. Cieslowski
1	1507	D.D. Moran
1	1560	G.R. Hagen
1	1568	A.E. Baitis
1	1568	N.K. Bales
1	1568	S.L. Bales
1	1568	G.G. Cox
5	1568	D. Woolaver
1	1572	M.D. Ochi
1	1572	Z.G. Wachnik

Copies	Code	Name
5	1572	J.Peters
1	16	H. Chaplin
1	1630	A.G. Ford
10	5211.1	Reports Distribution
1	522.1	Library (C)
1	522.2	Library (A)

DTNSRDC ISSUES THREE TYPES OF REPORTS

1. DTNSRDC REPORTS, A FORMAL SERIES, CONTAIN INFORMATION OF PERMANENT TECHNICAL VALUE. THEY CARRY A CONSECUTIVE NUMERICAL IDENTIFICATION REGARDLESS OF THEIR CLASSIFICATION OR THE ORIGINATING DEPARTMENT.

2. DEPARTMENTAL REPORTS, A SEMIFORMAL SERIES, CONTAIN INFORMATION OF A PRELIMINARY, TEMPORARY, OR PROPRIETARY NATURE OR OF LIMITED INTEREST OR SIGNIFICANCE. THEY CARRY A DEPARTMENTAL ALPHANUMERICAL IDENTIFICATION.

3. TECHNICAL MEMORANDA, AN INFORMAL SERIES, CONTAIN TECHNICAL DOCUMENTATION OF LIMITED USE AND INTEREST. THEY ARE PRIMARILY WORKING PAPERS INTENDED FOR INTERNAL USE. THEY CARRY AN IDENTIFYING NUMBER WHICH INDICATES THEIR TYPE AND THE NUMERICAL CODE OF THE ORIGINATING DEPARTMENT. ANY DISTRIBUTION OUTSIDE DTNSRDC MUST BE APPROVED BY THE HEAD OF THE ORIGINATING DEPARTMENT ON A CASE-BY-CASE BASIS.